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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 401

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C. October 31, 1916

MARKETING AND DISTRIBUTION OF WESTERN MUSKMELONS[1] IN 1915.

By O. W. SCHLEUSSNER, *Assistant in Market Surveys*, and C. W. KITCHEN, *Market Station Assistant.*

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INTRODUCTION.

During the season of 1914 the Department of Agriculture received a great many complaints from growers in the United States with reference to glutted markets and ruinous returns to all engaged in the muskmelon industry. The Office of Markets and Rural Organization responded to the calls for assistance by sending special investigators to certain melon-growing sections, for the purpose of making a study of marketing conditions, and the investigators of the office

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[1] Although the term "cantaloupe" is in wide commercial use in the United States at the present time, particularly in the irrigated districts of the West, the name belongs to a distinct botanical variety of this species and is restricted to that variety in commercial use in countries outside of the United States. The term "muskmelon," therefore, is used in this bulletin in conformity with the language of Food Inspection Decision No. 166, issued by the Department of Agriculture March 29, 1916.

NOTE.—This bulletin is of interest to muskmelon growers in the West, shippers, dealers, transportation companies, and consumers, and to all engaged in the trade.

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located in the large markets were instructed to give particular attention to muskmelons. The results of these studies have been made public.[1]

These studies were continued in 1915 in connection with an experimental market news service which was conducted for strawberries, tomatoes, muskmelons, and peaches. An intensive study of the most important melon-producing districts of the United States was made, and, as growers in the irrigated districts of the West suffered especially from the disastrous markets of 1914, special attention was given to these regions. In addition to market reporters covering the large cities during the muskmelon season, field representatives were stationed in the Imperial Valley district of California, the Salt River Valley district of Arizona, and the Rocky Ford district of Colorado during the entire shipping season. In addition, the Moapa section of Nevada and the Turlock district of California were visited by one of the authors during the shipping season.

IMPERIAL VALLEY DISTRICT, CALIFORNIA.

HISTORY.

The Imperial Valley is the earliest and probably the most important muskmelon-growing district in the United States to-day. The growth in production since 1905 has been remarkable, the increase being very close to 1,600 per cent in the 10 years since that time. The following table shows the total shipments per year from 1905 to 1915:

TABLE 1.—*Total shipments of muskmelons from Imperial Valley, 1905–1915.*

	Carloads.		Carloads.		Carloads.
1905	297	1909	1,411	1913	3,502
1906	577	1910	1,621	1914	4,448
1907	644	1911	2,580	1915	4,722
1908	1,891	1912	2,887		

During the season of 1915, 8,156 acres were planted to muskmelons. A portion of this area was abandoned or did not produce a good crop. However, the average yield of 185 crates of marketable melons per acre, making a total for the section of 4,722 cars of 320 crates each, shows the ability of this valley to produce abundant crops of muskmelons. The early and prolonged shipping season, extending from May 25 to July 21 in 1915, gave the valley a very considerable advantage in disposing of the crop.

The melons produced are largely of the green-meated (also called white-meated) varieties, the Early Waters and Eden Gem predominating. A few "pink meats," or Burrell Gems, are grown, but do not form an appreciable part of the total. The entire acreage is produced under irrigation and, in general, the growing is handled successfully according to the most approved methods. The acreages of the individual growers vary from 10 or 15 acres to 100 or more, and some firms grow several hundred acres. The expansion of markets, however, has not kept pace with the expansion of acreage.

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[1] See Gail, A. D., Sherman, W. A., and Yeaw, F. L. "Cantaloupe marketing in the larger cities with car-lot supply, 1914." U. S. Dept. of Agriculture, Bul. 315, 1915; and More, C. T., and Branch, G. V. "The commercial grading, packing, and shipping of cantaloupes." U. S. Dept. of Agriculture, Farmers' Bul. 707, 1916.

MARKETING ARRANGEMENTS.

Contracts Between Growers and Distributors.

The most striking feature of the marketing arrangements in the Imperial Valley is the contract in vogue between the growers and certain individuals, firms, or corporations, acting as shippers or distributors, who contract to handle and sell muskmelons for the growers at a stipulated commission of 15 per cent.

The shippers or distributors generally consign the melons to their main offices or to their connections in the eastern markets. They guarantee to make certain advances of money to the growers, which consist, first, of an advance at the time the contract is signed, generally $10 per acre, and of further per-acre advances during the growing season at the discretion of the distributor and according to the needs of the grower. When active shipping commences, the distributor further makes a per-crate advance at the beginning of each week covering all crates shipped by the grower during the previous week. In 1915 this per-crate advance varied from 57 to 77 cents per "standard," "jumbo," or "pony" crate.[1] The distributor deducts from this per-crate advance a certain amount to cover the cost of crate material, which is furnished by him, and a varying amount to repay the per-acre loans made earlier in the year. A general season's average net return, equal to the amount advanced per crate, is usually guaranteed by the distributor.

During the season of 1915 there were 14 firms shipping muskmelons from the Imperial Valley who controlled acreages by contract as described, and several other large shippers who grew their own melons. Copies of contracts were secured from 11 of those who advanced money on crops. All of these advanced $10 per acre as an initial loan, and most of them made additional per-acre loans of $5 or more. The per-crate advances of the 11 averaged 66 cents on the standard, pony, and jumbo crates, and 22.4 cents on "flats."

REASONS FOR CONTRACT SYSTEM.

At first glance, a contract system binding the grower to sell through a certain distributor at 15 per cent commission may seem undesirable; but it is based on the grower's inability to finance the raising of his crops. The muskmelon industry is a highly specialized and risky one, so that local banks which were interviewed in the muskmelon sections generally have been unwilling to make crop loans unless other security than the muskmelon crop itself was made the basis of the loan. Very few growers in the Imperial Valley are able to furnish the security which is required.

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[1] For definitions of crate see Farmers' Bul. 707.

The distributor usually employs a trained man, who inquires carefully concerning the grower's affairs before closing any contracts and who keeps in close touch with all developments during the growing season. Further, the distributor's agent usually stipulates the variety and also supplies the seed to be used by the grower. He often advises with reference to methods of planting and growing, picking and packing, and furnishes the material necessary for harvesting operations. Because of his close touch with the situation, the precautions taken before making any loans, and the protection given such loans by careful marketing of the crop, the distributor is willing to furnish money to the grower when others do not consider it safe to do so. At present, therefore, there seems to be no satisfactory alternative for the contract system.

FORM OF CONTRACTS.

In general, all contracts between distributors and growers are similar. The following sample is made by using clauses from contracts of several distributors, and is typical in that it embodies all of the main points of the 1915 contracts:

Agreement and Contract.

This contract and agreement, entered into this .... day of ......, 191.., by and between ...., of ...., hereinafter referred to as the GROWER, and ...., of ...., hereinafter referred to as the DISTRIBUTOR,

Witnesseth: That for a cash consideration mentioned in paragraph ten of this contract and agreement, the Grower hereby appoints the above-mentioned Distributor his exclusive selling and distributing agent for all cantaloupes grown, owned, or controlled by the Grower for the season of 1915, and agrees to pay the Distributor as compensation for his services, a commission of fifteen (15 per cent) per cent of the amount of the gross sales of all cantaloupes delivered to and accepted for shipment by the Distributor at the shipping shed at ......, California.

The Grower agrees to plant or have planted ...... acres of cantaloupes, from seed to be furnished or recommended by the Distributor, and to deliver to the Distributor at the above-mentioned shipping shed in a properly matured condition, all cantaloupes of merchantable quality, packed in standard crates, 12 x 12 x 23½ inches, containing forty-five (45) cantaloupes; or pony crates, 11 x 11 x 23½ inches, containing forty-five (45) or fifty-four (54) cantaloupes, and if, in the opinion of the Distributor the conditions warrant, flat crates, 4½ x 13½ x 23½ inches, containing twelve (12) cantaloupes, each and every crate to contain cantaloupes of uniform size and quality.

The Grower further agrees to use his best efforts to produce the best quality of cantaloupes, as early in the season as possible; to pick, pack, and handle the same in a strictly first-class manner, using proper care in every respect to prevent injury from any cause, and to deliver the said cantaloupes to the shipping shed in wagons provided with proper springs to prevent bruising, the cantaloupes to be properly protected after picking from exposure to the direct rays of the sun.

The Distributor agrees to perform the following:

"First. To provide a shipping shed through which to load all cantaloupes accepted by the Distributor for shipment, for the use of which the Grower hereby agrees to pay the Distributor a shed fee of not to exceed one (1c.) cent per crate for every crate accepted and shipped by the Distributor, said shed fee to be deducted from the cash advance hereinafter provided for.

"Second. To provide and sell to the Grower cantaloupe seed of first quality at one dollar and twenty-five ($1.25) cents per pound. To furnish to the Grower the following supplies at prices named, to wit: Registered paper wraps bearing the ...... Brand trade-mark, at eighty (80c.) cents per thousand, and in consideration of this price it is hereby agreed by the Grower that he will not ship any cantaloupes wrapped in the above-mentioned paper wraps except through the above-mentioned Distributor; nails at five dollars ($5.00) per keg; standard, pony, and jumbo crates at sixteen (16c.) cents each, and flat crates at nine (9c.) cents each, complete, including registered label bearing the ...... Brand, for which no charge is made, and it is understood that this label is loaned to the Grower, and the Grower hereby agrees that crates bearing this label shall be used only for such shipments of cantaloupes as are made through the above-mentioned Distributor under this contract. It being expressly understood that the Distributor shall not be liable to the Grower for failure to furnish such crates or other material or supplies if prevented from doing so by strikes or other causes beyond the control of the Distributor.

"Third. In consideration of the above clause, the Grower hereby irrevocably agrees that the terms under which the above supplies are sold to him will not be violated at any time during the shipping season and that under no circumstances will any portion of said crop be shipped through any other agency than through the Distributor, and hereby agrees that in the event that he violates said terms, or permits others to violate said terms, and ships or permits to be shipped any cantaloupes comprising said crop through any other agency without the written consent of the Distributor, that the prices named herein for supplies and material of every kind are null and void, and that he accepts said material, seed, crates, wraps, nails, etc., at an advanced price of twenty-five per cent above the prices mentioned in this contract, and that his entire season's supply is to be charged to him at said advanced prices. The said increased amounts over and above prices mentioned in this contract are to be credited to the "Surplus account" of the Distributor and, at the ending of the season said amounts are to be prorated, in accordance with the actual number of the crates shipped by other growers shipping through the Distributor, and are to be paid on that basis to the growers who have not violated their contract and whose interests have been injured by the shipment of said cantaloupes through other agencies by said Grower.

"Fourth. To advance to the Grower ...... cents per crate for all standard, pony, and jumbo crates of cantaloupes and ...... cents per crate for all flat crates of cantaloupes delivered by the Grower and accepted by the Distributor for shipment (except as may herein be otherwise provided for or agreed upon) less the average cost of crates, paper wraps, and nails, namely, twenty (20c.) cents for full-size crates and ten (10c.) cents per crate for flat crates, for all crates, paper wraps, and nails delivered to the Grower. the Distributor reserving the privilege to withdraw the advance on all varieties of crates excepting Fancy Standard and Fancy Jumbo crates containing forty-five (45) cantaloupes each upon twenty-four (24) hours' notice to the Grower, such notice to be given to the Grower either in writing or by posting same at the shipping shed. In case of an oversupply of cantaloupes, where, in the opinion of the Distributor, the markets of the country are in danger of being overstocked, the Grower agrees upon one day's notice from the Distributor to reduce his deliveries to five crates per acre per day of Fancy Standards or Fancy Jumbos, packed forty-five to the crate. Payment of advance to be made the Grower every Monday for all such advances due him for deliveries made during the previous week.

"Fifth. To furnish the necessary lumber to load and ventilate cars, also inspectors and laborers to inspect and load into the cars all accepted crates of cantaloupes at the expense of the Distributor.

"Sixth. The Distributor further agrees to guarantee freight and refrigeration charges on all cars of cantaloupes shipped by him for the account of the Grower, excepting in cases of strikes and lockouts, in which case the Grower agrees not to offer any cantaloupes for shipment if so requested by the Distributor.

"Seventh. The Distributor agrees to use his best efforts and endeavors in the marketing of said cantaloupes in order to secure the best possible results, and to create a pool including all shipments of cantaloupes made by the Distributor each two days and send the Grower a statement showing the average net result of such pools as soon as possible after the sale of said shipments and as soon as possible after the close of the season to make settlement with the Grower and pay the Grower all moneys due him from the sale of his shipments after deducting for all advances, seed, and material; it being understood that the net results realized from the sale of all crates of cantaloupes shipped during the entire season shall average not less than ...... cents per crate for the full-size crates and ...... cents for the flat crates.

"Eighth. The original account of sales covering the sale of every car shipped by the Distributor for the account of the Grower shall be open for the inspection of the Grower at any time within six months after the shipments of cars, and such account of sales shall show damages and claims placed against the railroads, if there are any claims for damages filed.

"Ninth. The Distributor agrees to file damage claims with the railroads over which the cantaloupes are transported for all just claims for damages which may occur to cantaloupes while in transit; and to make all possible effort to collect such damage claims, and as soon as possible after same are collected, to pay to the Grower the amount of his proportion of the claims collected, less fifteen (15 per cent) per cent, which may be retained by the Distributor, and less all legitimate costs incurred in collecting such claims.

"Tenth. The Distributor agrees to advance, as a loan to the Grower, ten ($10.00) dollars per acre for each acre of cantaloupes which the Grower agrees to plant and ship under this contract, and said ten dollars per acre loan shall be deducted by the Distributor out of the crate advances made to the Grower at the rate of ...... cents per crate for all crates shipped by the Grower until said ten dollars per acre loan has been paid to the Distributor. However, it is understood and agreed that the acreage and crate advance hereinbefore provided for shall not be made on cantaloupes that may be planted by the Grower on land upon which another crop has been planted during the same season.

"Eleventh. In consideration of the acreage advance and guaranteed crate advance agreed upon in this contract, paragraphs fourth and tenth, the Grower hereby irrevocably assigns to the Distributor for collection any interest of every character which he may have in any claim or claims against any transportation lines interested in the transporting of the cantaloupes accepted under this contract, and agrees to pay to the Distributor fifteen per cent on gross amounts so collected, also legitimate expenses incurred in making said collections, and by mutual agreement between the Grower and the Distributor, any moneys so collected due the Growers are to be prorated when finally collected among all Growers shipping through said Distributor, on the basis of the total crates shipped by each Grower during said season.

"It is further understood and agreed between the Distributor and the Grower that no cantaloupes shall be received from wagons which are not in line for unloading at the shipping point at ten o'clock p. m.

"It is further mutually agreed between the Distributor and the Grower that the inspector furnished by the Distributor shall make inspection of all the cantaloupes delivered for shipment by the Grower, and his decision on grade, quality, and pack shall be final and binding on both parties hereto.

"In witness whereof the parties hereto have hereunto set their hands and seals on the day and year first above written."

....

....

By ....

Witness:

....

UNFAVORABLE FEATURES OF PRESENT CONTRACTS.

A careful study of the foregoing typical contract shows that the pooling arrangements in general use possibly may work an injustice to the producer, because all types of packages are included in one pool. As the distributor is paid a commission on gross sales, it is to his advantage to handle as many muskmelons as possible during the season, provided his average net return does not fall below the amount of his guaranty. It may happen that although standards are selling at prices which are returning good margins over the guaranteed season average, ponies are selling at prices which result in actual loss to the producer. By averaging the two classes of packages, the distributor may be protected on his advance and may secure a larger commission by handling more cars than he would if ponies were not shipped. Meanwhile, the grower is receiving a smaller return than he would if he shipped only standards. This inequity could be overcome by maintaining separate pools for standards and ponies.

A further disadvantage of the contract system has been that in the past it has had a tendency to encourage the packing of muskmelons of poor quality. In other seasons the advances were higher than in 1915, sometimes being as high as 85 cents. This amount was in excess of the cost of production and guaranteed the grower a profit on every crate shipped. Under such conditions there has been an inclination to pack as many crates as possible, regardless of quality. Some growers have even gone to the extent of "facing" the crates by putting good melons on the outside and packing poor ones in the middle. Under such circumstances the growers have depended on their advances for profit instead of depending upon the production of high-class goods, which would bring good prices. The result has been to cause a deterioration in the average quality, which has injured the reputation of Imperial Valley muskmelons. The importance of cooperation between growers and distributors to obtain good quality can hardly be overestimated.

POSSIBILITIES OF COOPERATION.[1]

The contract advance system of marketing appears to be established firmly in the Imperial Valley because of the financial situation, but there still seems to be possibilities for cooperation among growers. This is particularly evident in the purchase of supplies. At present all seed used is furnished to the grower by the distributor at an average price of $1.25 per pound, and crate material is furnished at a cost of 20 cents per crate, including labels, nails, and paper wraps for melons. While these prices are by no means exorbitant, they do, nevertheless, include a satisfactory profit to the distributor, which might be retained by the grower. A growers' organization by making purchases of such material might effect desirable economies; but although the saving probably would be worth while, it would not be as large as might be expected at first glance, as large quantities of crate material must be carried over from year to year and must carry interest, insurance, storage, and shrinkage charges.

A growers' cooperative organization would be effective also in taking upon itself the verifying of the distributor's books at the end of each season. Good business principles alone demand that an effective check of all sales be made at least once a year. A standard form of account sales should be insisted upon. Each account sale should show the market in which the car was sold, the date it arrived, the date it was sold, and the various prices which the different packages brought. Occasionally cars are sold outright in a single sale. In such cases the name of the buyer should be indicated and the various prices per crate shown. Many eastern receivers acting as agents for western muskmelon distributors are lax in making a detailed account sales.

QUALITY.

Because of the heavy transportation charges involved the California muskmelon is distinctly a semiluxury in the large markets of this country. The only exception is in the markets of the Pacific coast, to which the freight rates are low, so that the melons can be delivered at a moderate price. The muskmelon is an article liked by many but necessary to none. Because of this fact quality is of prime importance. Inferior or tasteless melons are entirely unsatisfactory to the consumer, and the frequent purchasing of muskmelons of such quality will cause him to discontinue buying them. In some seasons the quality of the Imperial Valley melons has been unsatisfactory, due in part to the contract conditions already explained. Although the season of 1915 witnessed some improvement in the average grade shipped, greater improvement is desirable.

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[1] See Nahstoll, G. A., and Kerr, W. H. "A system of accounting for cooperative fruit associations." U. S. Dept. of Agriculture, Bul. 225, 1915.

The necessity for good quality has been so widely recognized that in 1915 the State of California passed an act establishing a standard grade for muskmelons which must be adhered to in the future.

Comparisons of Returns on Muskmelons of Good and Poor Quality.

The 1915 season demonstrated beyond question the fact that only high-quality melons give profitable returns. The differences in the selling prices of various brands were very marked and consistent throughout the season, those of good market quality bringing uniformly good prices and those of poor quality the reverse. The average prices received from the sale of cars of four typical brands in four markets on three different days are compared below (Table 2). A and B contained brands of consistently good quality and sold for higher prices than C and D, which contained two poorer brands. The cars were sold side by side on the various markets, and no effort was made to select cars showing particularly good or bad sales, the individual cars having been picked at random.

Table 2.—*Average prices received per crate for muskmelons from the Imperial Valley in four markets on certain days.*

	New York.	Chicago.	Pittsburgh.	St. Louis.
June 19.				
Good quality:				
A	$2.40	$2.75	$2.50	$2.10
B	2.25 to 2.50	2.25 to 2.75	2.25 to 2.65	2.25
Poor quality:				
C	1.75	1.25	1.50	None sold.
D	None sold.	None sold.	1.70	None sold.
June 30.				
Good quality:				
A	2.50	2.75	2.50	2.25
B	2.50 to 2.75	2.00 to 2.30	2.15	2.00
Poor quality:				
C	None sold.	None sold.	None sold.	None sold.
D	1.90	1.65 to 1.75	1.75	1.75 to 2.00
July 10.				
Good quality:				
A	2.00	2.25	2.50	None sold.
B	2.25 to 2.50	2.00 to 2.25	None sold.	None sold.
Poor quality:				
C	1.25	1.50	None sold.	None sold.
D	2.05	None sold.	1.78	None sold.

The Ideal Market Melon of the Gem Type.

As a market term, the word "quality" has a broad meaning. A melon of good quality for market purposes must be not only of good flavor and texture, but also of the size and shape desired by the market, of good appearance, possess good carrying qualities, and be properly picked, packed, and handled. A comparison of the quality of any two brands is merely a comparison of the nearness to which they approach perfection.

Size.—The market desires a uniform melon, both as to size and shape. The 45-size standard cantaloupe is the most popular and profitable, and if melons vary from this size they should run larger rather than smaller. A few jumbos can be marketed to advantage, although these generally do not average as high in price as standards. Figures covering the net returns of one large distributor for the entire season of 1915 indicate that the average net returns per crate for jumbos was 76 per cent of the price realized for standards. Probably this may be accepted as typical when a fairly heavy supply of jumbos is moving. There is no basis for comparison between ponies and standards, as pony shipments were discontinued on account of low prices after the first few weeks. It can be said, however, that ponies are seldom profitable after a few early shipments.

Netting.—In addition to uniformity in size and shape, a thick, heavy netting, entirely covering the melon, is desired. Ideally, this should be so thick and heavy and stand out so prominently that the ground color of the melon is hardly visible. Such netting is considered an indication of good carrying quality and is therefore preferred by dealers.

Cavity.—The muskmelon should be thick walled, with a small cavity, and the texture of the meat should be fine grained rather than coarse. The seed should be attached firmly to the wall of the cavity. Melons of this character have been observed to possess somewhat better carrying qualities than those with large cavities or coarse flesh. Early varieties are generally less satisfactory as to cavity than those maturing somewhat later.

Color of flesh.—During 1915 another factor in determining popularity was the coloring of the flesh. Green-meated muskmelons with a pink or salmon-colored lining were most in demand, because of their pleasing appearance when cut. A number of strains of melons with this pink lining were used, and the distributors securing the best results usually shipped such melons. Certain strains of pink-meated melons which were used in 1915 possessed most of the characteristics essential to high quality.

Flavor.—Flavor is the determining factor in quality. A muskmelon may arrive on the market in splendid condition and with fine appearance, but will not give satisfaction unless its flavor is good. In fact, all other desirable characteristics are of importance only as they are accepted as indications of fine flavor or table quality.

Varieties.—The various factors of quality which have been described are all more or less characteristic of specific varieties of melons. In 1915 three varieties of green-meated melons were widely used in the Imperial Valley, these being the Early Waters and various strains of the Eden Gem and Pollock. The Early Waters ripened early, and therefore some sold at the early high prices, but after it came into competition with other varieties it was at a disadvantage because of its poorer quality, the high percentage of ponies produced, and its large cavity. The cavity of the Early Waters was so large as to have a decided effect on the average weight per crate. The figures shown in Table 3 were furnished by the official weighing bureau of the Southern Pacific Co., and represent the average weight per crate of the entire shipments of various distributors taken on the days indicated. While some of the differences in weights are due to the varying skill of different packers, the results taken as a whole indicate quite clearly that the Early Waters is not as solid or heavy a melon as the other varieties. Sales in the market show that it is regarded as decidedly inferior to other melons from this district.

TABLE 3.—*Average weight per crate of certain shipments of muskmelons from the Imperial Valley.*

Variety.	Dates.	Standard.	Pony.	Flats.
	1915.	*Pounds.*	*Pounds.*	*Pounds.*
All Eden Gems	June 8–15	69.00	60.70	28.45
Do	June 10	....	....	29.90
Mostly Eden Gems	June 7, 10	66.20	59.00	26.65
All Eden Gems	June 8, 15	66.00	57.30	....
All Eden Gems and Pollock	June 7	66.00	57.95	25.5
All Eden Gems	June 7, 8	65.64	57.26	27.8
Eden Gems and Early Waters	June 7, 8	65.00	58.00	28.50
Mostly Early Waters	June 7	64.83	55.64	....
Early Waters and Eden Gems	June 10, 11	64.66	55.76	....
Mostly Early Waters	June 7	64.47	57.8	25.00
Do	June 11	64.30	55.38	....

Percentage of ponies.—Because of generally unprofitable returns from ponies, good marketing practice makes it desirable to reduce their number as much as possible. The proportion of ponies to standards depends on the fertility of the land, the care taken in growing, and the variety. The Early Waters produced a higher percentage of ponies than any other variety largely grown in 1915.

Because of conditions not entirely understood, the proportion of ponies in the entire crop of 1915 was excessive, amounting to 74.7 per cent of the total number of crates shipped, according to actual count made on June 3, 4, and 5. After this date many of the pony melons were not packed.

As every pony-sized melon lost is an economic waste, an excess should not be produced. That the proportion of ponies to standards can be controlled to some extent by the variety planted is indicated by the figures in Table 4, showing the percentage of ponies to standards shipped on certain days. Shippers A, B, and C were shipping only Eden Gem melons, while the others were shipping varying proportions of Early Waters. The Eden Gem produced at least 50 per cent or more of standards, while shipper K, who had a very large percentage of Early Waters, could secure only 13 per cent of standards.

TABLE 4.—*Percentages of ponies and standards shipped on certain days from the Imperial Valley.*

Shipper and date.	Standards.		Ponies.		Total number of crates.
	Number of crates.	Percentage.	Number of crates.	Percentage.	
Shipper A:					
June 2	134	46.4	155	53.6	289
June 3	417	59.7	281	40.3	698
June 4	1,051	57.1	787	42.8	1,838
Total	1,602	56.7	1,223	43.3	2,825
Shipper B:					
June 2	178	46.8	202	53.2	380
June 3	492	52.4	447	47.6	939
June 4	1,142	57.5	842	42.5	1,984
Total	1,812	54.8	1,491	45.2	3,303
Shipper C:					
June 2	216	42.0	301	58.0	517
June 3	432	48.0	470	52.0	902
June 4	858	43.0	1,138	57.0	1,996
Total	1,506	44.0	1,909	56.0	3,415
Shipper D:					
June 2	114	38.0	183	62.0	297
June 3	173	32.0	372	68.0	545
June 4	650	38.0	1,042	62.0	1,692
Total	937	37.0	1,597	63.0	2,534
Shipper E:					
June 2	188	31.8	405	68.2	593
June 3	368	26.3	1,032	73.7	1,400
June 4	454	27.2	1,218	72.8	1,672
Total	1,010	27.5	2,655	72.5	3,665
Shipper F:					
June 2	15	14.0	94	86.0	109
June 3	26	9.0	250	91.0	276
June 4	130	30.0	294	70.0	424
Total	171	21.0	638	79.0	809
Shipper G:					
June 2	10	12.0	76	88.0	86
June 3	18	12.0	132	88.0	150
June 4	50	25.0	150	75.0	200
Total	78	17.9	358	82.1	436
Shipper H:					
June 2	118	12.0	831	88.0	939
June 3	208	10.0	1,934	90.0	2,142
June 4	652	18.0	2,887	82.0	3,539
Total	978	14.7	5,652	85.3	6,620
Shipper J:					
June 2	218	15.4	1,200	84.6	1,418
June 3	343	13.1	2,259	86.9	2,602
June 4	802	18.0	4,579	82.0	5,381
Total	1,363	14.5	8,038	85.5	9,401
Shipper K:					
June 2	183	12.0	1,323	88.0	1,506
June 3	417	14.0	2,615	86.0	3,032
June 4	618	13.0	4,014	87.0	4,632
Total	1,218	13.2	7,952	86.8	9,170

Proper maturity.—The picking of the melons at the proper stage of maturity[1] is important in securing good eating quality. The necessity of allowing melons to mature properly can not be emphasized too strongly, as the shipping of green melons is probably the quickest way in which to ruin the demand in all markets. Distributors seem to recognize the importance of good eating quality more keenly than do the growers, and have tried to insist on the inspection of melons before shipment and the rejection of all immature stock. Shippers and growers must cooperate if the green melon is to be eliminated from the market.

INSPECTION.

Before the 1915 season it had been customary to make all inspections on a sorting platform before loading the crates into cars. It is very difficult, and often impossible, to make a thorough inspection after muskmelons are packed, especially if the melons are wrapped, as the majority are in the Imperial Valley.

During the 1915 season certain distributors established a field-inspection system, either as a substitute for or in addition to the platform inspection. Competent, experienced inspectors in the field, keeping a watch over and advising pickers as to the proper stage of maturity and keeping an oversight on packing, have been a great help in the production of better grades. Such field inspection can prevent the improper picking and packing of stock instead of merely rejecting such stock after it is packed, as is the custom with platform inspection.

PACKING.

Imperial Valley growers can also improve their quality by providing proper packing facilities.[1] Many of the packing sheds are of the crudest sort, having rough wooden sorting bins, with no padding, into which melons are tossed, sometimes from a considerable distance. Padded or canvas-bottomed bins should be provided and melons should be placed in them carefully and not thrown.

IMPORTANCE OF QUICK HANDLING.

In an extremely hot climate, like that of the Imperial Valley, where the daily maximum temperature usually exceeds 100° F., muskmelons ripen rapidly between the time they are picked and the time they are placed under ice. Undue delay in placing them under ice at the shipping point probably is the most frequent cause of soft and overripe melons on the market. The shorter the time between picking and actually placing the muskmelons under refrigeration, the more mature they may be allowed to become on the vine. Under ideal conditions they should be in the car and under ice within a few hours after they are picked. In at least one case where this was attempted a decided improvement in quality on arrival at market was obtained.

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[1] See Farmers' Bulletin 707.

Under ordinary conditions picking and packing are often done by the same individuals, who go into the fields and pick for several hours, and then go into the packing shed and pack. Meanwhile, the melons have been exposed to the heat. After they are packed they are again allowed to stand in the packing shed exposed to the warm winds until a full load is accumulated; often they are held until several loads are ready. Teamsters have been seen to deliver melons at the sorting sheds after midnight. The distance of melon fields from the railroad station is a factor which must not be overlooked when providing for efficient handling of the crop.

After muskmelons reach the loading shed the crates must be sorted into piles, according to grade and size, and usually a further delay occurs before they are loaded. Melons have been observed standing on loading sheds from a few hours to more than 10, and in one case for over 24 hours, part of the time in the direct rays of the sun. These delays must be eliminated or reduced if satisfactory quality is to be secured.

Effect of Contract Labor on Quality.

Most of the work of harvesting muskmelons in the Imperial Valley is contracted for by the firms or individuals who employ large gangs of men, brought to the valley for the harvesting season. Picking and packing is very seldom done by the grower himself, but is contracted for at an average rate of 20 cents per crate. Hauling from the packing to the loading sheds is let to teaming contractors at an average price of about 4½ cents per crate. Finally, the loading of the crates from the shed into the cars is not often done by the distributor himself, but is also done by contract. The contractor is interested chiefly in securing a good profit and is inclined to contract for more work than he can handle efficiently, and to try to economize on labor. The grower virtually loses control of the handling of his own goods, and is unable to expedite the work, even if he wishes to do so. The result has been delay at every step. It is not apparent that the grower or distributor is unable to handle his own business as economically as the contractor and certainly he can do so more efficiently.

A further bad feature of the contract system is that it encourages the picking of immature melons and a bad pack. The contractor being paid according to the number of packed crates, is interested primarily in packing as large a number as possible. When melons are not ripening rapidly enough to keep his entire crew busy, the contractor is losing money, and the result is a tendency to encourage as close picking as possible, so that many melons are picked before being sufficiently mature. Likewise, there is an inclination to pack melons of doubtful quality in order to produce a large number of crates.

Quality of Wrapped and Unwrapped Muskmelons.

The question of the desirability of wrapped in contrast to unwrapped muskmelons is one which has been long discussed. In the season of 1915 many distributors in the Imperial Valley experimented with unwrapped melons, with generally unsatisfactory results. The unwrapped muskmelons in the majority of instances arrived on the market in an overripe condition. Reasons for this have not been established, the most plausible theory being that because of the very high temperature and warm winds the moisture in the melons evaporates very quickly after they are picked. Further, they change in temperature and ripen rapidly when deprived of the shade of the vines. It is believed that the paper wrap protects the melons not only from the hot winds but also somewhat from a rapid change in temperature between the time when they are packed and when placed in the car.

Whatever may be the reasons, it is certain that the distributors who wrapped their melons had fewer complaints of overripe stock than those who did not. One shipper decided not to wrap at the beginning of the season, but received so many complaints that in the middle of the season he decided to wrap all melons thereafter, and his complaints practically ceased. Market quotations everywhere indicated a preference for wrapped stock over the ordinary unwrapped. A few market quotations received are given below:

June 21, New York: Receipts, 23 cars. Stock mostly good condition, wrapped stock being given preference by the trade at higher prices than unwrapped.

June 24, St. Louis: Three cars arrived. Standards, unwrapped, $2; wrapped, $2.25.

June 29, Kansas City: Unwrapped standards, $1.50 to $1.75, mostly $1.50; wrapped, $1.75 to $2, mostly $1.75.

However, the question of wrapped or unwrapped muskmelons can not be dismissed without reference to one certain brand which was packed unwrapped the entire season with great success, usually topping the markets at prices well in advance of all others. This brand, however, was picked and packed with special care, and the melons were placed under ice promptly without the usual delays. This proves that under favorable conditions and with proper care muskmelons may be packed unwrapped and shipped to any market successfully.

The fact remains that under the average conditions in the Imperial Valley unwrapped melons did not prove a success in 1915, and probably will not until picking and packing methods have been more nearly perfected, and until the unnecessary delays between the field and iced car have been eliminated.

DISTRIBUTION.

The distribution of the western melon crop differs from that of most other crops, as it is handled almost entirely on consignment. This is due to its highly perishable nature, coupled with the long haul to market and the extremely rapid daily increase in the number of cars shipped after the season begins, all combining to make f. o. b. purchasing so risky that it is seldom attempted by eastern dealers.

The same factors which make it hazardous for the eastern buyer to purchase f. o. b. shipping point make it necessary for the shippers to exercise great care in distribution if disastrous returns are to be avoided. Quick handling of the goods is essential, as a delay of a few days or even one day en route may cause melons to be overripe. Likewise, if best results are to be obtained, it is desirable that refrigeration be continuous from the time that cars are shipped until they arrive at their final destination, and that car doors remain unopened during the entire time. For these reasons diversions and inspections en route should be avoided, and it is highly desirable that direct distribution be secured at the shipping point.

Not only should the distribution be direct, but it must be wide, as during the crest of the movement every possible outlet must be used if the grower is to receive an adequate return for his labor. Further, the distribution should be efficient; that is, markets should receive supplies in proportion to their consuming capacity.

The determination of the proper supply for various markets is difficult, as it does not vary directly as the population. Certain small markets take larger daily supplies at profitable prices than do other larger markets. For the purposes of discussion, profitable prices are assumed to be prices which will net the grower a return equal at least to his cost of production.

COST OF PRODUCTION.

The exact cost of production per crate for Imperial Valley muskmelons is not a matter which can be determined with scientific accuracy, as it varies with the fertility of the land, the business ability of the grower, the rate of production per acre, and various other factors. Estimates of cost per crate made by different growers vary considerably. One of the largest individual growers and shippers figures his total cost at 60 cents per crate on board cars, while many others believe 80 cents about correct. Table 5 is believed to be a conservative estimate of the average cost per acre, being compiled after interviews with many growers of long experience. These figures are based on a labor cost of $2.25 per day per man. The value of horse labor is figured at 75 cents per day per single horse. Cultivation is figured at the rate of 4 acres per day.

TABLE 5.—*Average cost of production per acre of muskmelons in the Imperial Valley.*

	Low.	Average.	High.
Rent per acre	$10.00	$22.50	$40.00
Plowing per acre (hired)	....	3.00	....
Disking per acre	....	.75	....
Leveling per acre	....	.50	....
Seed (at $1.25 per pound)	1.90	2.00	2.25
Planting (2 acres per day)	....	1.13	....
Thinning and hoeing	....	2.25	....
Cultivating (4 times)	....	3.00	....
Training vines out of furrows	....	1.00	....
Watering (about 15 times) through season, at 50 cents per acre-foot	1.50	2.00	2.50
Total	....	41.88	....

Yields are variable. One shipper controlling 722 acres in 1913 reports an average yield of 167 crates per acre at one shipping station and of 222 crates at another. For 1914 the same shipper reports a grand average of but 126 crates per acre on 562½ acres. General opinion places 175 crates per acre as a good average yield, although this is somewhat lower than the 1915 yield, which was 185 crates per acre. On the basis of 175 crates per acre, the per-crate cost of production is 23.9 cents. Further costs are as follows:

TABLE 6.—*Total cost per crate on board cars of muskmelons from the Imperial Valley.*

Picking and packing (by contract)	$0.20
Crates, nails, and wrappers	.20
Hauling (average cost by contract)	.045
Shed fee	.01
Total	.455
Growing cost	.239
Cost on board cars	.694

The average grower, therefore, must receive a return of approximately 70 cents per crate before he is repaid for his labor.

CONSUMING CAPACITIES OF MARKETS.

As a guide to consuming capacities of the various markets at prices returning the grower his net cost of production, Table A (in envelope at end of bulletin) is presented, showing the daily receipts of Imperial Valley melons in all markets throughout the United States during the past season and the average returns from such markets, net to the grower, after commissions and charges are deducted. These figures cover returns on every car sold by 11 of the 16 large shippers, approximately 3,500 cars, or 75 per cent of the total shipments. Every car sold in every market is not included, and cars arriving in bad condition have been omitted, but there are a sufficiently large number to form a good basis for calculation.

In each case where it was available the average price for each sized crate in each car has been taken and the various brands on one market in any one day have been averaged together, both the best and poorest brands being included in the average price thus obtained. In some cases only gross or net sales per car were available, and in such cases the returns have been prorated as follows:

The manifests have been reduced to a basis of standards, by figuring 3 flats or 1 jumbo equal to 1 standard, while 1 pony has been considered equal to 70 per cent of a standard. This basis of calculation for ponies was arrived at by taking the average quotations from Monday, June 14, to Saturday, June 26 (two weeks of market days), on New York, Chicago, Pittsburgh, Philadelphia, St. Louis, Minneapolis, and Los Angeles markets. In each city it was found that during this representative period ponies were quoted at approximately 70 per cent of the value of standards. The exact general average of all such quotations for the ponies was a value of 72.8 per cent of standards. However, 70 per cent has been selected as a convenient and approximately accurate value for ponies as compared with standards. After the number of packages recorded on the manifests had been reduced to the equivalent of standards the total number of standard crates so secured was divided into the net return of the entire car to obtain the average price for standards.

Under each date the column marked R represents receipts, or the number of cars arriving on the market on that date. The column marked P contains the average net price to the grower for the various sizes of crates. The sizes of the crates are designated by the letters S for standards, P for ponies, F for flats, and J for jumbos. In some cases an apparent discrepancy exists in the prices, as returns from ponies or flats will appear to be greater than the returns for standards. Such cases are due to a heavy supply of poor standards on the market, which pulled down the average price of standards, while all ponies or flats sold were of high quality.

In some cases diversions were made of which no records were secured, so that some prices were obtained at points where there were apparently no cars. With such a large movement and so many different factors it is impossible to secure absolute accuracy.

The column headed "Capacity" represents the capacity of each market to consume muskmelons at prices returning at least 70 cents per crate (the production cost as figured above) net to the grower expressed in terms of carloads per day (D) or per week (W). These figures are based on the returns of 1915.

The estimates of consuming capacity can not be considered absolutely correct, but are merely approximate. They are based on 1915 conditions, and can not be applied with exactness to any other year. Further, they can not be determined exclusively from returns. The quality of arrivals may be the cause of poor returns, and though a car may show a loss to the grower, this may not be due to an oversupplied market, but to the unmerchantable quality of the goods. The figures presented are founded, first, on returns secured in 1915; second, on the quality of goods sold in each market; and, finally, on the opinion of dealers of long experience whose knowledge of conditions extends over many seasons. It is believed that these figures are the most nearly accurate which have been worked out. The estimates of consuming capacities of southern markets are based only on conditions prevailing in the early part of the season before local competition commenced.

It is possible that consuming capacities in succeeding years may be a trifle larger, as it must be remembered that during the Imperial Valley season in 1915 market conditions were not favorable to the consumption of muskmelons. The largest crop on record was moved in a season beginning nine days later than in 1914, when the next largest crop was moved. The weather in the eastern markets during this period was the coldest and rainiest known for many years. The only favorable feature was the unusually poor quality of the bulk of southern melons which came on the market in competition with Imperial Valley stock in July.

By referring to Table A it may be seen that receipts in most markets frequently have surpassed the estimated consuming capacity, and the result was necessarily a net loss to the grower. This may be avoided to some extent by efficient distribution, but there have been times each season when, due to extremely heavy shipments, practically all the available markets of the United States have been oversupplied.

The chart shown in figure 1 represents graphically the daily shipments of 1913, 1914, and 1915. The heavy line drawn across the page at 148 cars represents the estimated maximum daily *profitable* consuming capacity of the United States. When the movement exceeds this number of cars, growers should restrict their shipments or be prepared to stand a loss, since muskmelons can not be stored successfully. It will be seen that at various times in the past three years the total shipments have amounted to more than the total estimated consuming capacity of the entire United States.

It must not be imagined, however, that the estimates contained in this bulletin represent the ultimate consuming capacity of the individual markets in any case or of the United States as a whole. Much opportunity exists to broaden market outlets and to develop the consuming capacity of the markets now in use. Table 7 lists the total quantities of Imperial Valley melons consumed by the various markets in the United States in 1914 and 1915. A study of this table shows that some 20 new markets that had never before received carloads received direct shipments of muskmelons in the past season, some of them receiving several cars. On the other hand, 40 markets which received straight cars in 1914 received none in 1915. During the 1915 season markets west of the Rockies as a rule largely

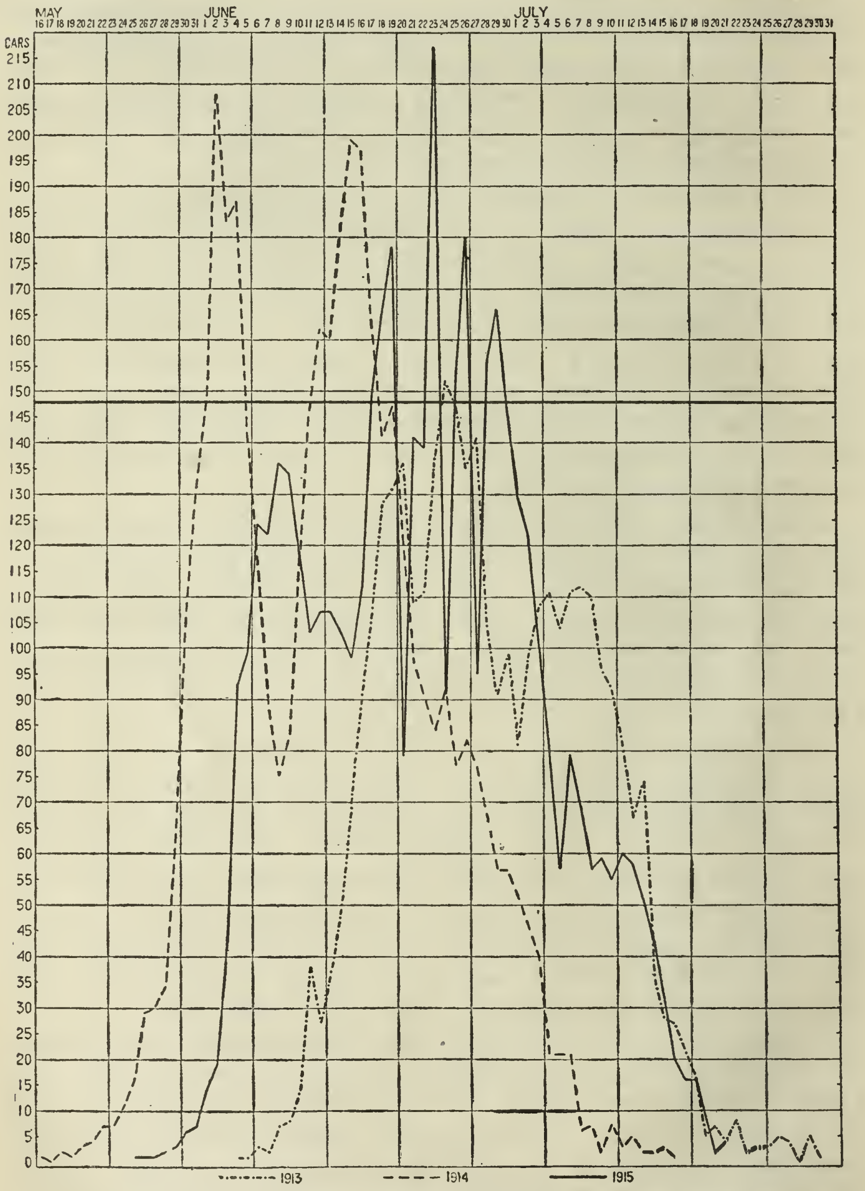

FIG. 1.—Chart showing the daily shipments of muskmelons, 1913, 1914, and 1915.

increased their consumption of Imperial Valley muskmelons, while many of the eastern markets decreased their consumption.

Unquestionably many towns which have not handled muskmelons by full carloads in the past could be developed to do so. Cities which have been using steady supplies in the past years may be developed to consume larger quantities. That consumption does not depend entirely upon the size of the city is demonstrated by the fact that in 1915 Pittsburgh consumed 184 more cars of melons at as good average prices as Philadelphia, a city more than twice its size. A possible reason for this is the fact that for many years several of the most important muskmelon distributors in the United States have had their headquarters in Pitttburgh, and melons have been pushed vigorously on the market.

TABLE 7.—*Statement of destinations of muskmelon shipments from Imperial Valley.*

Destination.	Number of cars.		Destination.	Number of cars.	
	1914	1915		1914	1915
Aberdeen, S. Dak	2	0	Eugene, Oreg	0	4
Akron, Ohio	10	5	Evansville, Ind	11	8
Albany, N. Y	18	8	Everett, Wash	0	3
Albuquerque, N. Mex	5	8	Fargo, N. Dak	1	2
Altoona, Pa	18	9	Fern, Nebr	1	0
Amarillo, Tex	1	0	Flint, Mich	3	0
Ansonia, Conn	1	0	Fort Smith, Ark	2	0
Arkansas City, Kans	1	0	Fort Wayne, Ind	1	1
Bakersfield, Cal	1	3	Fort Worth, Tex	8	4
Baltimore, Md	34	42	Fremont, Nebr	0	1
Bay City, Mich	1	4	Fresno, Cal	5	14
Beaumont, Tex	3	2	Gallup, N. Mex	0	1
Bellingham, Wash	0	1	Grand Forks, N. Dak	4	6
Billings, Mont	4	5	Grand Island, Nebr	0	5
Binghamton, N. Y	2	0	Grand Rapids, Mich	12	4
Birmingham, Ala	5	3	Great Falls, Mont	4	5
Bismarck, N. Dak	1	0	Hannibal, Mo	1	0
Bloomington, Ill	1	1	Harrisburg, Pa	4	4
Boise, Idaho	0	2	Hartford, Conn	14	1
Boston, Mass	225	210	Hastings, Nebr	1	2
Bradford, Pa	1	0	Havre, Mont	0	1
Bridgeport, Conn	7	3	Helena, Mont	6	4
Buffalo, N. Y	59	79	Hornell, N. Y	0	1
Burlington, Iowa	7	9	Houston, Tex	8	5
Burr Oak, Iowa	0	1	Huntington, W. Va	1	0
Butler, Pa	1	0	Hutchinson, Kans	6	8
Butte, Mont	18	21	Independence, Kans	5	2
Calgary, Alberta, Canada	3	4	Indianapolis, Ind	39	30
Cambridge, Ohio	4	4	Ithaca, N. Y	1	0
Canton, Ohio	8	10	Johnstown, Pa	3	3
Cedar Rapids, Iowa	4	10	Joplin, Mo	12	9
Charleroi, Pa	1	0	Kalispell, Mont	0	1
Chicago, Ill	507	689	Kansas City, Mo	128	90
Cincinnati, Ohio	99	114	La Crosse, Wis	4	7
Clarksburg, W. Va	7	3	Lewiston, Idaho	0	2
Cleveland, Ohio	87	74	Lexington, Ky	2	1
Coffeyville, Kans	2	1	Lima, Ohio	5	1
Colton, Cal	11	7	Lincoln, Nebr	22	14
Colorado Springs, Colo	6	11	Little Rock, Ark	9	4
Columbus, Ohio	47	37	Long Beach, Cal	0	3
Crawford, Pa	0	4	Los Angeles, Cal	279	299
Cumberland, Md	5	5	Louisville, Ky	26	13
Dallas, Tex	15	10	Madison, Wis	3	0
Danville, Ill	1	0	Mansfield, Ohio	1	0
Davenport, Iowa	9	7	Mason City, Iowa	2	0
Dayton, Ohio	14	12	Massillon, Ohio	1	0
Decatur, Ill	1	0	McAlester, Okla	1	0
Denver, Colo	45	71	McKeesport, Pa	3	1
Des Moines, Iowa	19	28	Memphis, Tenn	22	20
Detroit, Mich	48	40	Miles City, Mont	0	1
Douglas, Ariz	0	4	Milwaukee, Wis	31	27
Dubois, Pa	6	2	Minneapolis, Minn	66	69
Dubuque, Iowa	1	3	Missoula, Mont	2	4
Duluth, Minn	9	6	Moberly, Mo	2	0
Easton, Pa	1	0	Montreal, Quebec, Canada	11	2
Elmira, N. Y	11	11	Muscatine, Iowa	0	2
El Paso, Tex	30	29	Muskogee, Okla	5	4
Erie, Pa	11	4	Nashville, Tenn	8	1

TABLE 7.—*Statement of destinations of muskmelon shipments from Imperial Valley*—Continued.

Destination.	Number of cars.		Destination.	Number of cars.	
	1914	1915		1914	1915
Newark, N. J	6	12	Scranton, Pa	11	8
New Castle, Pa	3	3	Schenectady, N. Y	1	0
New Haven, Conn	9	0	Seattle, Wash	79	91
New Orleans, La	24	23	Sherman, Tex	1	0
New York, N. Y	571	639	Sharon, Pa	1	0
North Adams, Mass	2	4	Sioux City, Iowa	13	18
Oakland, Cal	30	55	Sioux Falls, S. Dak	3	0
Ogden, Utah	2	3	South Bend, Ind	4	1
Oklahoma, Okla	19	14	South Lincoln, Nebr	1	0
Omaha, Nebr	67	93	Spokane, Wash	17	22
Ottumwa, Iowa	2	5	Springfield, Ill	6	9
Peoria, Ill	18	14	Springfield, Mass	6	12
Philadelphia, Pa	243	207	Springfield, Mo	2	1
Phoenix, Ariz	4	8	Springfield, Ohio	4	2
Pittsburg, Kans	1	0	Stockton, Cal	0	6
Pittsburgh, Pa	344	391	Syracuse, N. Y	15	6
Pittsfield, Mass	2	4	Tacoma, Wash	13	17
Pocatello, Idaho	2	10	Terre Haute, Ind	1	1
Portland, Oreg	67	83	Toledo, Ohio	21	10
Portland, Me	4	3	Topeka, Kans	31	21
Providence, R. I	22	18	Toronto, Ontario, Canada	12	12
Pueblo, Colo	7	4	Tracy, Cal	1	0
Regina, Saskatchewan, Canada	1	1	Troy, N. Y	9	2
Riverside, Cal	0	2	Tucson, Ariz	4	5
Rochester, N. Y	4	3	Tulsa, Okla	13	9
Rockford, Ill	3	5	Turner, Iowa	1	0
Rock Island, Ill	0	1	Twin Falls, Idaho	1	0
Rock Springs, Wyo	1	0	Utica, N. Y	7	10
Roseville, Cal	0	3	Wallace, Idaho	1	0
Sacramento, Cal	29	44	Washington, D. C	32	25
St. Joseph, Mo	18	13	Waterloo, Iowa	4	3
St. Louis, Mo	156	122	Watertown, N. Y	2	0
St. Paul, Minn	9	12	Wheeling, W. Va	14	9
Salina, Kans	4	6	Wichita, Kans	19	15
Salt Lake City, Utah	16	20	Wilkes-Barre, Pa	4	4
San Antonio, Tex	3	3	Williamsport, Pa	3	3
San Bernardino, Cal	1	0	Winnipeg, Manitoba, Canada	3	0
San Diego, Cal	16	26	Worcester, Mass	6	0
San Francisco, Cal	136	210	Youngstown, Ohio	10	8
San Jose, Cal	13	18	Zanesville, Ohio	5	2
Santa Barbara, Cal	1	0			

Much has already been done in the way of developing markets, as is proven by the fact that in 1908 a crop of 1,891 cars was marketed at prices ruinous to all concerned, probably causing heavier losses than any other crop in the history of the industry, while now a crop of twice that size can be handled easily with profit. While the work of educating the public is tedious and often expensive, the broadened markets which result make it worth while.

SALT RIVER VALLEY DISTRICT, ARIZONA.

HISTORY.

The Salt River Valley district of Arizona begins to ship muskmelons at about the time when shipments from the Imperial Valley begin to decrease. In 1915 the first car was shipped from Mesa on July 4, and the last car was shipped from Glendale on August 1.

Muskmelons have been grown commercially since 1908, but shipments have not increased appreciably since 1911, as is shown by the following record of total output.

TABLE 8.—*Total shipments of muskmelons from Salt River Valley district, 1908–1915.*

Year.	Mesa.	Glendale.	Total.	Year.	Mesa.	Glendale.	Total.
	Cars.	*Cars.*	*Cars.*		*Cars.*	*Cars.*	*Cars.*
1908	276	56	332	1912	161	223	384
1909	161	121	282	1913	113	220	333
1910	66	49	115	1914	342	163	505
1911	472	240	712	1915	320	145	465

Growers generally do not specialize in the production of melons, but grow only a few acres, as part of a scheme of diversified farming. The muskmelon fields are usually much smaller than in the Imperial Valley, varying from 2 to 40 acres, there being only one field of "pink meats" as large as 75 acres in 1915. The average patch in the Salt River Valley is under 10 acres. This is forcibly illustrated by the fact that the largest distributor, who shipped about 200 cars, had contracts with over 80 growers.

The varieties grown include both the green-meated melon (principally the Eden Gem) and the pink-meated or Burrell Gem, the acreage being about evenly divided between the two. The growers surrounding Glendale specialize in "pink meats."

MARKETING ARRANGEMENTS.

Marketing arrangements are much the same as in the Imperial Valley, the grower entering into a contract with a distributor to market all of his muskmelons through the distributor at a commission of 15 per cent.

The contracts differ from those in the Imperial Valley in only a few particulars, the general language being much the same. For instance, advances are made on a basis of a certain amount per crate, plus the crate material, which is technically furnished by the distributor as an added item, the cost being afterwards deducted from the returns. This difference is one of form rather than of substance. In 1915 the advance on green-meated melons ranged from 25 to 50 cents per standard crate, from 15 to 30 cents per pony crate, and from 30 to 40 cents per jumbo crate, the average being 35 cents for standards, 22½ cents for ponies, and 35 cents for jumbos, the crate being furnished in addition. The advances on pink-meated muskmelons ranged from 12 to 15 cents per flat crate, depending on the size and pack of the melons. In addition to the per-crate advance, a $10 per-acre loan usually is made to growers, payable in two or three installments during the growing season, the first loan of $5 generally being made either about the 1st of April, or when the melon fields show 80 per cent of a perfect stand. The per-crate advance is generally considered to be a guaranteed season average net return.

Two other special features of the contracts are a clause contained in some of them binding distributors to wire net results obtained from each car as soon as it is sold; and another allowing the distributor to discontinue the advances at any time by giving the grower 24 hours' notice. Neither of these provisions is contained in the contracts made in the Imperial Valley.

POSSIBILITIES OF COOPERATION.

Although the growers in the Salt River Valley have been organized in the past, there was no association in active operation in 1915. The opportunities for saving on purchases of materials and supplies through cooperation are much the same as those which exist in the Imperial Valley. Crates and nails for green-meated muskmelons are furnished to growers by distributors at 15 cents for standards, no paper wraps for melons being included. A charge of 10 cents is made for each flat. This price, however, includes the paper wraps for the "pink-meat" melons. Figures obtained indicate that this represents a gross profit of about 3 cents on standard crates. and approximately 2 cents per crate on flats. However, from this gross profit there must be deducted the cost of labels and labeling, the shrinkage, breakage, insurance, storage, and interest charges.

Seed which is now furnished to the growers at $1.25 per pound could be purchased by an association in large lots at prices from 30 to 40 cents less than this. It is probable that a saving amounting to considerable in the aggregate could be obtained by cooperative purchasing.

QUALITY.

Picking and Packing.

The problems of securing quality are much the same as in the Imperial Valley, except that conditions are more favorable. Because of small acreages a great many growers are able to do their own picking and packing, with a consequent improvement in the average quality.

Packing is carried on in open sheds much like those in the Imperial Valley. Wrappers are used only for the Burrell Gem melons, and then only for the sake of appearance. While packing is generally fairly satisfactory, room for improvement exists, as is shown by the difference in weights in the following table of tests (Table 9), taken on the same day, covering different brands but the same varieties of melons. These weight tests are the average of an entire day's shipments.

TABLE 9.—*Average weight tests of different varieties of muskmelons from the Salt River Valley, Arizona, on one day.*

Brand.	Green meats.				Pink meats.		
	Standard.	Pony.	Two-thirds jumbo.	Jumbo flat.	Jumbo flat.	Standard flat.	Pony flat.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
A	68			28.1	26.9		
B	69.3						
C			53.5				
D	69.5	58.3		27.2			
E	70.3		54.1		27.4	27.2	26.2
F			56.1			31.1	25.1

EFFECTS OF CONTRACT LABOR.

Some of the work of harvesting is done by contract, as in the Imperial Valley, the charges for picking and packing being 8 to 10 cents for flats and as high as 22 cents for standards. Where work was done by contract there were often complaints and there were some rejections on account of poor quality. An example of losses incurred on account of contract work was observed at the end of the shipping season when a contractor, who was anxious to complete his job and discharge his crew, entirely stripped a field of muskmelons, picking them so green that 600 crates were rejected by the shipper on account of immaturity and were practically a total loss to the grower. Instances of this kind did not occur where the grower did his own work.

QUICK HANDLING.

The hauling of the muskmelons is done almost entirely by the growers themselves. Because of warm weather there exists the same necessity for quick handling as in the Imperial Valley. In a field of melons under observation the inspector was seen to criticize the picking early in the morning, on account of the slightly green condition of the melons. The packing was delayed and the melons were allowed to remain exposed to the heat the entire day, not being hauled to the loading shed until late in the evening, when a number of melons were overripe from undue exposure to heat. Hauling must be done promptly if good quality is to be obtained.

INSPECTION.

Growers are unable to depend upon inspectors to any great extent to guide them in securing proper quality, for as a result of small and scattered acreages a constant field inspection can not be maintained by the distributors. Platform inspectors generally visit various fields for a few moments each morning and spend the rest of the day on the loading platform, inspecting melons as they are brought in by the ranchers. This system seems to work satisfactorily under Arizona conditions.

Percentage of Ponies.

Because of proper selection of varieties and favorable climatic conditions in 1915, the percentage of ponies was very small as compared with the Imperial Valley. It is very doubtful if quality could be improved in this respect, as the losses from excessive production of pony melons were very small. The fact that the per acre yield is somewhat less than in the Imperial Valley may be an influencing factor in the production of a smaller percentage of ponies. Records of shipments taken from July 6 to 9 are as follows:

Table 10.—*Percentages of ponies and other melons shipped from the Salt River Valley.*

Shipper.	Green meats.					Pink meats.			
	Ponies.	Jumbos.	Standards.	Two-thirds jumbos.	Jumbo flats.	Pony flats.	Jumbo flats.	Standard flat 12's.	Standard flat 15's.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
A	7.0	30.3	38.5	11.0	14.2	13.3	15.1	52.0	19.6
B	16.4		83.6			6.7		50.0	4.3
C	7.7		41.7		50.6	11.9		88.1	

DISTRIBUTION.

Returns to Growers.

Distribution problems in all western melon sections are practically the same. Results in Arizona in 1915 were especially favorable, because of the almost total failure of the Indiana crop and the generally poor quality of melons from eastern sections which usually compete with Arizona. Pools of season averages, published by two distributors, show, in Table 11, the returns to Salt River Valley growers in 1915.

Table 11.—*Average returns per crate to two Salt River Valley growers during 1915 season.*

	Green meats.			Pink meats.	
	Shipper A.	Shipper B.[1]		Shipper A.	Shipper B.[1]
Two-thirds jumbos	$0.80	$0.667	Standard flat 12's	$0.364	$0.385
Standard	1.107	1.00	Standard flat 15's		.30
Jumbo flats	.365		Pony flats		.195
Ponies	.683	.58	Jumbo flats		.41
			Ponies (45's and 54's)	.714	

[1] Approximate.

Cost of Growing.

The actual records of growing costs taken from a large field of "pink-meat" melons at Glendale are as follows:

Table 12.—*Cost of production per acre of muskmelons at Glendale, Salt River Valley.*

Land rent	$10.00
Plowing	2.50
Disking and harrowing	3.00
Furrowing	.75
Seed	1.50
Hoeing	3.60
Cultivating	2.00
Turning vines	.65
Labor of irrigating	1.90
Irrigation water	1.00
Cleaning ditches	$0.20
Picking crates used in field	1.00
Picking and packing, 400 flat crates per acre, at 9 cents	36.00
Hauling melons from field to shed	4.00
Hauling 400 flat crates from shed to town, at 1 cent	4.00
Total	72.10

As this field produced 400 flat crates of "pink meats" to the acre, the total cost was 18 cents per crate, to which must be added 10 cents for crates, nails, and wrappers, making the cost on board cars 28 cents.

In the Mesa district, where most of the green-meated muskmelons are grown, an estimate of costs was obtained from the grower of a large field of Eden Gems. The figures are based on a labor cost of $2.50 a day per man and 75 cents a day per horse. The cultivation is based on the rate of 4 acres a day per man with a single horse. The following figures cover a typical melon field and are believed to represent the average, although it is known that costs in other fields may vary considerably from this:

Table 13.—*Cost of production per acre of muskmelons from Mesa district, Salt River Valley.*

Rent	$15.00
Plowing, first time	3.00
Plowing, second time	3.00
Harrowing, disking, and leveling	3.00
Seed, at $1.25 per pound	1.00
Planting 5 acres per day	.50
Thinning and hoeing	2.25
Cultivating 4 times	$3.25
Training vines	1.25
Water about 10 times, at 50 cents per acre-foot	1.25
Total	33.50

Estimates of normal production in the Mesa district seem to agree that 150 crates per acre is a fair average. On this basis the growing cost of the above field was 22.3 cents per crate. The total cost per crate on board cars was, therefore, as follows:

Table 14.—*Total cost per crate on board cars of muskmelons from the Mesa district, Salt River Valley.*

Growing cost	$0.223
Picking and packing (by contract)	.22
Hauling	.03
Shed fee	.01
Crate material	.15
Total	.633

DISTRIBUTION IN 1915.

Table B (in envelope at end of bulletin) has been prepared to show the actual results obtained in the various markets at different times during the 1915 season, in order that it may be used as a partial guide in the future. However, the figures shown in this table can not be relied upon entirely, as competitive shipments from other points will greatly influence the results obtained. Because of a crop of poor quality in the East in 1915, the competition received by Arizona melons was below normal. Further, in calculating the results which may be obtained in any market, the competition from other western sections, such as the Imperial Valley and the Moapa and the Turlock districts, must be considered very seriously. Therefore, no attempt has been made to draw up any definite table of the consuming capacity of various markets for Arizona melons, as there are too many factors which vary from year to year. However, a careful study of the net returns secured by the grower in 1915 (cost of package not deducted) should be a valuable aid in the selection of markets in the future.

MOAPA DISTRICT, NEVADA.

HISTORY.

Commercial muskmelon growing in Nevada is confined to the Moapa Valley, this being a narrow valley extending from Moapa, on the main line of the San Pedro, Los Angeles & Salt Lake Railroad, southeastward for about 20 miles, which is served by a branch line of the railroad. The district is an old one, having been shipping yearly since 1906. The industry has not developed rapidly, as the acreage necessarily is limited by scarcity of water, the entire valley depending on warm springs for its irrigation water. However, the acreage planted has increased slightly nearly every year. In 1910 there was a decrease, due to unsatisfactory returns the year before. Yearly shipments since 1906 are shown in Table 15.

TABLE 15.—*Total shipments of muskmelons from Moapa district, Nevada, 1906–1915.*

	Cars.		Cars.
1906	21	1911	97
1907	15	1912	119
1908	56	1913	159
1909	165	1914	299
1910	75	1915	276

The beginning of the shipping season follows very closely upon that of Arizona, extending from July 7 to August 4 in 1915. The acreages are generally not large, the crop being handled rather as a side issue. Except for a small number of Indians residing on a neighboring reservation, no labor except that of the resident ranchers is available during the rush of harvesting, and the harvesting work and packing must be done largely by local help. The green-meated varieties are grown exclusively.

MARKETING ARRANGEMENTS.

For a number of years marketing has been handled almost exclusively by one firm of distributors at a commission varying according to the sections of the United States in which the cars have been sold, 17½ per cent being charged in the territory north of Denver and Salt Lake and west of Minneapolis, and 15 per cent in the remainder of the country. No information is available regarding advances.

QUALITY.

All melons are shipped unwrapped. The quality and pack has generally been fairly satisfactory, although it could be improved by methods suggested for other sections.

DISTRIBUTION.

For many years Moapa Valley muskmelons have been marketed almost exclusively in western cities, only a few cars going to eastern points. As a result of the scarcity of good muskmelons in the eastern section in 1915 a larger number of cars than usual were shipped east. Table C (in envelope at end of bulletin), showing the receipts of western muskmelons on the markets during the Nevada season and the prices obtained for Nevada melons on the various markets, illustrates the success met with in the different cities.

The results obtained in 1915 were good, and certain of the smaller western markets were used to very good advantage. It is probable that the distribution could be broadened if necessary to provide for increased acreage. The only obstacle in the way of going farther afield for markets is the fact that in the past the growers in the Moapa Valley have been accustomed to picking their melons for delivery in the near-by western markets; consequently it is not unlikely that most of the melons may be a trifle too soft for shipment to distant points. In fact, some complaints to this effect have been heard in the markets, but such objections could be easily overcome.

TURLOCK DISTRICT, CALIFORNIA.

HISTORY.

The Turlock district is located in the San Joaquin Valley in the vicinity of Turlock, Cal., which is the principal shipping station, a majority of the cars being shipped from this point. The area of the district is not large, and the growers are resident ranchers exclusively, very little or no land being rented for the purpose of growing muskmelons. The patches generally are not large, and are cared for by the owners as part of a plan of diversified farming. The varieties grown are very largely the green-meated, especially various strains of the Eden Gem and Pollock. Only a small acreage of Burrell Gems is grown. The district is notable in that it is the only western muskmelon section not depending upon surface irrigation. Although the San Joaquin Valley is supplied with water for irrigaiton, and alfalfa and grain fields are irrigated freely, the growers depend entirely upon subirrigation or seepage to supply the necessary moisture.

The muskmelon crop was not generally very profitable prior to 1915. Shipments were limited by unsatisfactory market conditions in previous years, and only a portion of the crop was moved. In 1915 the markets were good, and shipments continued for a long season, car lots going out from July 20 until October 4. The following figures show the difference between shipments in 1914 and 1915:

To—	1914	1915
	Cars.	*Cars.*
East	539	1,350
West	120	204
Total	659	1,554

So far as could be learned, the acreage was substantially the same in both years, and the production about the same. Had the market been as satisfactory in 1914 as in 1915, it is not improbable that the same number of cars could have been moved. In other words, it seems probable that half of the crop of 1914 was lost for lack of markets.

MARKETING ARRANGEMENTS.

Muskmelons probably have been marketed in a greater variety of ways at Turlock than in any other western sections. In previous years large numbers were purchased from the farmers' wagons by buyers stationed in the railroad yards, but this was not so much the case in 1915. Fairly large acreages were contracted to distributors to be marketed at a charge of 15 cents per crate. So far as is known, there were no advances made in any of these contracts. A cooperative organization was formed, which handled a considerable tonnage for 15 cents per crate. After a 5 per cent dividend was paid on the stock, any surplus was to be returned to the growers at the end of the season, being prorated on the basis of the volume of shipments offered by each grower.

QUALITY.

The quality of Turlock muskmelons during the 1915 season was generally satisfactory, although not uniform. The prices at which different brands sold on the market varied considerably. Certain brands also were very uneven, some very good packs and some very poor being observed in the same cars. No wraps were used on any of the Turlock melons.

DISTRIBUTION.

The question of distribution is fully as important in Turlock as elsewhere. The 1915 season was the first in which muskmelons from this region were shipped successfully to eastern markets in any considerable quantities. Because of the scarcity of good melons in the East at precisely the time when Turlock was shipping, and because of the lateness of the Rocky Ford season and the poor quality shipped therefrom, the Turlock district practically had the market to itself so far as muskmelons of high quality were concerned.

As a result of these conditions, the returns were remarkably good and the season very successful. However, it remains an open question whether Turlock melons can invade the eastern markets and pay a profit to the growers in normal seasons, when a fair quantity of good local melons are available.

Table D (in envelope at end of bulletin) has been prepared to show the net returns received by the growers on the different markets of the United States from day to day. This table covers practically the entire shipments of the season and contains figures covering approximately 1,400 cars of the total number of 1,554 cars. The only information available in each case was the net return to the shipper and the manifest of the individual cars. The manifests of the cars were reduced to a basis of standards by considering ponies equal in value to 70 per cent of a standard and by considering flats equal to 33⅓ per cent of a standard. The total standards secured by such a method were divided into the net amount received by the distributor, and this is taken as a net return per standard. In each case the distributor's or association's selling charge must be deducted from the figures quoted in order to secure the net amount to the grower. Since selling charges vary, distributors' commissions have not been deducted. The figures quoted in each instance are averages; that is, the various brands appearing on one market for any one day were averaged together.

This table is presented merely as a basis of comparison between various cities and as a record of the season's results. It should not be accepted as an assurance of what may be expected in other seasons with the same volume of shipments, as conditions in competitive areas were not normal in 1915. The next season may show entirely different results, but the chart may be used as an index of the comparative success with which different markets were used in 1915.

COLORADO DISTRICT.

HISTORY.

The Arkansas Valley district of Colorado is the oldest, and for many years was the heaviest, western muskmelon-producing area in the United States. It is divided into two distinct sections, the

Rocky Ford district, located along the line of the Santa Fe Railroad, which raises about 80 per cent green-meated muskmelons and 20 per cent pink-meated; and the Ordway district, which is about 15 miles north and northwest of the Rocky Ford district, located along the line of the Missouri Pacific Railroad and devoted exclusively to the pink-meated Burrell Gem variety. Some stations as far as 60 to 80 miles east of Rocky Ford also ship a number of cars of muskmelons, and these points are usually considered a part of the Rocky Ford district, although they are separated by a stretch of country in which no melons are grown. The production in Colorado has increased somewhat of late years, but by no means in the same proportions as in the Imperial Valley. The decided decrease in production in 1915 may be attributed to a short crop, due to late spring frost and a backward season. The following is a table of shipments for several years.

TABLE 16.—*Total shipments of muskmelons from Colorado district, 1908–1915.*

	Rocky Ford district.	Ordway district.[1]
	Cars.	*Cars.*
1908	615	....
1909	1,129	....
1910	1,324	....
1911	1,235	....
1912	1,132	....
1913	1,695	....
1914	1,732	942
1915	789	228

[1] No figures available until 1914.

The Colorado shipping season is the latest of any of the highly important regions, extending from August 30 to October 13 in 1915, but this was abnormally late.

The acreages of individual growers are generally small, varying from 2 to 20 acres, with only a few patches which are larger. The muskmelon crop is one of a number of important crops, but few growers specialize in it. The crop is marketed almost entirely under contract between growers and distributors, although there is some cash buying by distributors and commission men on the ground during the season, which amounts to a small proportion of the total shipments. The terms of contracts differ in the two districts.

MARKETING ARRANGEMENTS.

ROCKY FORD CONTRACTS.

In the Rocky Ford section there are two distinct classes of growers—the tenant-farmer growers and the landowner growers. The former are generally unable or unwilling to finance the growing of their crops, and their marketing arrangements are usually based on a guaranteed-advance-per-crate type of contract. Under such contracts in 1915 the advances were generally 50 to 55 cents per standard crate, 25 cents per flat crate, and in some cases 25 cents per pony crate, though the larger number of the distributors refused to make any advance whatever on pony melons. Under such contracts the crate material usually is furnished to the grower by the distributor at cost or at a price allowing the distributor a small margin of profit. Pools are made biseasonally—one for the shipments made in August and the second for all shipments from September 1 to the end of the season. The distributor reserves the privilege of discontinuing all advances upon 24 hours' written notice. The commission on the advance, as well as the no-advance types of contracts, is 15 per cent.

During the past year most of the owner growers adopted a contract which contemplated no advance payment per crate by the distributor. These owner growers generally do not need financial assistance in producing their crops. Under this contract as written the distributor performs no service but loading the cars and marketing them. These growers purchase their own material either individually or through their association. A feature of one such contract was that returns were made to the association without delay by the local agent of the distributing company on the same day that the car was sold in the eastern market, the result being telegraphed by his eastern connection. Further, copies of all account sales were mailed directly to the growers' association by the eastern agent of the distributor, these acting as a check on the wired amount.

It should not be inferred that no owner growers have contracts including advances or that all tenant growers have contracts with advances. No hard-and-fast rule can be set regarding contracts of the Rocky Ford district, but in a general way the various classes of growers in 1915 made contracts as indicated. A copy of a "no-advance" type of contract is given below:

Agreement and Contract.

This agreement made and entered into this 15th day of March, 1915, by and between ...., party of the first part, and ...., party of the second part.

Witnesseth: That,

Whereas party of the first part is at all times engaged in shipping, marketing, and distributing cantaloupes on commission; and

Whereas party of the second part is engaged in the growing of cantaloupes;

This agreement is such that the party of the second part agrees to plant 140 acres of cantaloupes, eighty (80) per cent Eden Gem variety and twenty (20) per cent Osage Gem variety, and properly prepare the ground, plant, cultivate, grade, and pack cantaloupes, making every effort to secure best quality of product, and deliver same to the said party of the first part in good merchantable condition, at the platforms: ...... for inspection, the inspectors to be furnished by the said party of the first part.

It is further agreed that for and in consideration of the party of the second part growing and delivering said cantaloupes, as aforesaid, the party of the first part shall receive same at loading stations at ......, advance all freight, refrigeration, and cartage charges on said cantaloupes to and at their destination, and deduct the same from gross sales, as herein provided.

The party of the first part further agrees to note on all account sales, as far as practicable, the shippers numbers on all such crates that are not up to grade.

It is further agreed that the party of the first part shall furnish all lumber and labor for loading cars at its own expense.

Party of the first part agrees to receipt party of the second part for all melons delivered, check same into the cars, and deliver duplicate of receipt book and car tallies to party of second part or its representative at the end of each week.

Party of the second part agrees to furnish all crates, nails, and wrappers, and cantaloupe seed, at its own expense, and to label properly all crates with labels to be furnished by party of the first part.

It is further agreed that the party of the second part does hereby appoint the party of the first part as its exclusive agent, to distribute, market, and sell all cantaloupes grown and shipped east by the party of the second part during the season of 1915.

It is further agreed between the parties hereto that all cantaloupes are to be matured properly and well graded, and that the inspector shall have full authority to refuse such cantaloupes as do not come up to these requirements. All cantaloupes are to be delivered in uniformly packed crates as follows:

Standards, 12 x 12 x 23½ inches in size, containing 45 cantaloupes each; jumbo flats, 4½ x 13½ x 23½ inches in size, containing 12 or 15 cantaloupes each; Osage Gems, 4½ x 13½ x 23½ inches in size, containing 12 or 15 cantaloupes each, properly wrapped. First party shall load all cantaloupes accepted by it as being in accordance with this contract, and shall strip the cars and have same billed in the name of .... to first party at such point or points as first party may deem proper, to be marketed. First party agrees to have the same marketed according to its best judgment and ability, and to report to first party's local agent at ...... by wire, separately, for each car, as soon as the same is sold, and said local agent shall at once give second party a check in full for the proceeds of said car, after deducting from the gross amount of sale, all charges for freight, refrigeration, and cartage, and also fifteen per cent upon the gross amount of such sale as first party's commission for its services hereunder; first party shall mail to party of second part duplicate of account sales of each and every car sold by each agent selling the same as soon as rendered by such agent. There shall also be deducted by first party a shed fee of one cent per crate on standard crates and one-third of one cent per crate on flats, to be held by first party and paid to the owners of the respective sheds at the end of the season, for the use of such sheds. There shall also be deducted by first party the sum of two per cent from the gross sales, as made, to create a fund out of which to pay any shortage that may arise during the season, in case any car or cars shall not pay freight, refrigeration, and cartage charges. At the end of the season any balance in such fund shall be paid by first party to second party, to be distributed by it to the growers furnishing such cantaloupes, in their proper proportions.

It is further agreed that the net sums paid to second party by first party from sales shall be distributed by second party to the growers according to their respective shares, and first party shall not be responsible for the making of such distribution by second party.

It is further agreed between the parties hereto that if the transportation company over whose lines said cantaloupes are transported requires a bond for payment of the transportation charges on said cantaloupes to their destination the said party of the first part will furnish satisfactory signers for such bond so required by the transportation company.

All of which is mutually agreed by and between the parties hereto.

In witness whereof the said party of the first part has caused this agreement to be signed on its behalf by its manager and said second party has caused the same to be signed in its name by its president and secretary the day and year first above written.

....
....
....

ORDWAY CONTRACTS.

In Ordway all contracts were made on the advance-per-crate basis in 1915, the crate material being furnished to the growers by the distributors either at cost or at a small margin above cost. All advances were likewise a guaranty of the season's average net return, but could be discontinued by the distributor at any time upon 24 hours' written notice. The average advance on standard flat or jumbo flat crates of Burrell Gems was 21 cents and the average advance on pony flats was 9 cents. The distributors uniformly received a compensation of 17½ per cent commission, the handling of Burrell Gem melons being said to be somewhat more expensive than the handling of the green-meated varieties.

COOPERATION.

Cooperation in the Colorado muskmelon districts is generally in a more advanced stage than in many of the other melon-producing sections. The growers are organized at practically all of the shipping stations, and contracts are made between associations and distributors rather than between individual growers and distributors. Some progress has been made in the direct purchasing of supplies by associations, and in most cases association officials make a fairly accurate audit and check of distributors' books. The work of the associations might be extended considerably to good advantage.

QUALITY.

CAUSES OF POOR QUALITY IN 1915.

The marketing of the 1915 muskmelon crop from Colorado was unfortunate and unsuccessful. This condition may be attributed almost entirely to the generally very poor quality of the melons shipped. This was due to several causes, including a late spring, which caused replanting and a late crop, and the harvesting of green melons. Other reasons were unseasonably cold and wet weather during the summer, causing slow growth, the presence of some rust, and the scarring of many of the melons by grasshoppers. Although these latter causes contributed to unsatisfactory quality, they were almost negligible compared to the damage caused by improper picking and packing.

Early market conditions probably were never more indicative of good returns for Colorado melons than they were during 1915. The season opened with the eastern markets almost entirely bare of muskmelons and with the public appetite for western melons whetted by the generally satisfactory quality of those from Turlock. In addition, the weather was abnormally hot and favorable to the consumption of melons in all of the eastern markets in the early part of September. The result was a strong demand for melons seldom equaled at that time of the year. For the first 10 days that Rocky Ford melons were upon the market, September 8 to 18, they sold at as good or better prices than the melons from Turlock, Cal. Normally, this state of affairs should have continued, for the California season was nearing its end and the quality of the melons was deteriorating, while the Colorado melons should have been at their very best.

However, on account of the danger of frost and the eagerness of Colorado growers to take advantage of the prevailing high prices, many of them picked all melons that were even fairly netted, whether they were matured or not. The situation was aggravated by the fact that certain cash buyers paid high prices for the first few cars of melons, although these were green.

After the public had bought Rocky Ford melons for a week with constant disappointment because of poor flavor, prices began to drop, and on September 17 Rocky Ford melons sold in Chicago at 75 cents per crate less than Turlocks, and in New York at $1 to $1.25 less. Up to that date prices for muskmelons from both sections had been identical. Prices of Colorados continued to decline rapidly and on September 23 standard crates sold as low as 50 cents each in Chicago and 75 cents each in New York, these prices being less than the cost of the freight itself. Later they sold even lower, and several instances were reported where entire cars were hauled to the dump and emptied. In some cities cars were condemned by the local health officials as being too green to be fit for food. The market prices of Colorado and Turlock melons in Chicago and New York from September 8 to September 21 are shown in Table 17.

TABLE 17.—*Market prices of Colorado and Turlock muskmelons in Chicago and New York.*

Date.	Chicago.				New York.			
	California.		Colorado.		California.		Colorado.	
	Standards.	Flats.	Standards.	Flats.	Standards.	Flats.	Standards.	Flats.
Sept 8	....	....	....	....	[1] $3.50	[1]$1.25–1.50		
	$2.00–2.25	....	....	$1.00–1.10	2.50–3.00	1.00–1.25		
9	....	$0.75–0.85	$2.25–2.50	.85–1.00	2.75–3.00	1.00–1.25	....	$1.25
10	2.00	.80– .85	2.50	[2].35–1.00	3.50	1.50	$3.50	1.25–1.40
11	2.50	....	2.50	1.00	3.75	1.50	....	....
13	2.75–3.00	....	3.00–3.25	1.25–1.40	[1] 5.00	[1] 2.25	....	....
					4.00–4.50			
14	2.75–3.00	....	3.00	1.50	4.00	1.50–1.75	4.00	1.65–1.75
15	2.75–3.00	1.15–1.25	3.00	1.15–1.25	3.50–4.00	1.50–1.75	3.00–4.00	1.00–1.25
16	3.00–3.25	1.15–1.30	2.75–3.00	1.15–1.25	3.50–4.00	1.75	....	[3] 1.75
								[4] 1.25–1.50
17	3.00–3.25	1.25–1.40	2.25–2.50	1.00	4.00–4.50	1.75–1.85	2.75–3.00	1.25–1.50
18	3.00–4.00	1.50–1.75	1.00–2.00	1.00	3.00–4.00	1.50–1.75	2.00–2.75	1.00
20	....	....	1.50–2.00	.75– .85	2.75–3.25	1.00–1.50	2.00–2.50	.75–1.25
					[1] 4.00	[1]2.00–2.25		
21	3.00–3.25	....	1.00–1.75	.65– .85	2.75–3.50	1.00–1.50	2.00–2.50	.50– .60
					[1] 4.00	[1] 2.00		
22	2.00–2.25	....	1.00–1.50	.65– .75	3.00–3.25	1.00–1.25	1.60–2.00	.60– .80
23	3.00–3.25	1.25–1.35	.50–1.25	.50– .75	2.00–2.50	....	.75–1.25	.65– .75
					[1] 3.25			
24	2.25–2.50	1.25	1.00–1.50	.65– .75	1.75–2.50	1.00–1.15	1.50–2.00	.65– .85
			[1]2.00–2.50	....	[1]2.50–3.00	[1]1.50–2.00		

[1] Fancy grade. [2] Green. [3] 12's. [4] 15's.

Dealers and consumers interviewed by representatives of the Office of Markets and Rural Organization stationed in the various markets reported that many of these green melons would not ripen, but rotted instead of maturing. Those which did appear to ripen merely became soft, but gained no flavor.

Not all growers shipped immature goods, as a few brands and a few marks were of fairly good quality, and obtained somewhat better prices. But such a large percentage of unsatisfactory stock was shipped that the whole market was injured, and consumption of Colorado melons dropped so low that even the best brands did not bring satisfactory prices. While it is true that prices naturally would have declined somewhat with the colder weather toward the end of the season, the main reason for the generally poor returns was the shipment of green melons.

GRADING, PACKING, AND WRAPPING.

Grading and packing usually are done in sheds in, or close to, the fields, the melons generally being sorted for grade but not for size before going to the packer. The packers size the melons during the packing operation. No wrappers are used on green-meated melons, but all pink-meated ones are wrapped.

INSPECTION.

Because of the small and scattered acreages, it is not practicable for the distributors to establish a field inspection service. Platform inspectors usually visit various fields for a short time each morning, but they are able at the most merely to give advice with reference to general conditions. The growers and distributors therefore depend largely upon platform inspection, which never can be entirely efficient without the hearty cooperation of the grower.

DISTRIBUTION.

While fairly good distribution of Colorado melons was secured in 1915, it had little effect on prices for reasons already explained. Table E (in envelope at end of bulletin) lists receipts of cars in various markets and the average prices actually secured in these markets in 1915. It is valuable only as an example of the impossibility of securing good results by efficient distribution when other factors necessary to success are lacking. No conclusions can be drawn from this table with reference to the consuming capacity or market preferences of any city.

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P	J		S	P	J		J		S	P	J

21	22		23		24		5		
Pr.	C	Pr.	C	Pr.	C	Pr.		Pr.	TOTAL RECEIPTS
$		$	1	$		$		$	5
					1	1.46 1.06			2
	1	.99 .59	1	.92 .52					12
									2
									3
	1	1.07	2	1.10	2	1.19			18

	18		1		20		4	5		6		
r.	R	Pr.	R	r.	R	Pr	Pr.	R	Pr.	R	Pr.	TOTAL RECEIPTS
		$		$		$	$		$		$	1 1
												2 1
												1 5
												1 8
												10 7

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 402

Contribution from the Bureau of Plant Industry.
WM. A. TAYLOR, Chief.

Washington, D. C. ▼ October 3, 1916

CEREAL EXPERIMENTS AT THE AKRON FIELD STATION, AKRON, COLO.

By George A. McMurdo,
Assistant, Office of Cereal Investigations.

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INTRODUCTION.

The experiments with cereals at the Akron Field Station[1] were begun in the fall of 1907. They have been conducted for the following purposes: (1) To determine the best crops, crop varieties, and strains for that section of Colorado; (2) to improve varieties by breeding; and (3) to determine the best methods of cereal production.

This bulletin contains the results of experiments conducted during eight years, 1908 to 1915, inclusive. A period of eight years should be sufficient to warrant drawing some fairly accurate conclusions. It is believed, however, that the production factors in this period have been rather more favorable than can be expected in a longer period.

The data herein presented should indicate the relative values of the cereals. They should also show the best varieties of each cereal for this district and for localities with similar conditions.

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[1] The Akron Field Station, Akron, Colo., is operated by the Office of Dry-Land Agriculture Investigations. The cereal experiments are conducted by the Office of Cereal Investigations in cooperation with the office named. These experiments were begun in 1907. Mr. Wilson G. Shelley was in charge from March 1, 1908, until Feb. 28, 1911. Mr. Clyde McKee was then appointed scientific assistant and placed in charge of cereal investigations at Akron, which position he retained till Feb. 15, 1913. He was then succeeded by Mr. Charles H. Clark, who remained till July 1, 1913, on which date he was transferred to take charge of flax investigations in the Office of Cereal Investigations. The writer of this bulletin was placed in charge of the cereal experiments at Akron on the date of Mr. Clark's transfer.

DESCRIPTION OF THE DISTRICT.

The district here described includes northeastern Colorado and small adjacent portions of southeastern Wyoming, southwestern Nebraska, and northwestern Kansas. The results presented are believed to be generally applicable to similar soils in this district. The river valleys and sand hills present very different conditions.

HISTORY.

The district described formed part of the Great American Desert in the early history of the trans-Missouri West. It was the feeding ground for the bison and antelope. The bisons were exterminated by hunters and only a few antelopes remain. The bisons were succeeded by large herds of cattle. Vast areas were controlled by the few cattlemen who held the scattered water holes or owned the adjoining river land.

With the building of the railroads up the valleys of the Platte and the Republican Rivers and of other lines to the south came the first real farm settlement. The free Government lands brought thousands of settlers who did not understand dry-land conditions. Many did not remain long enough to obtain patents to their homesteads. Many of those who did remain borrowed money on the land, and later the mortgages were foreclosed. The result was that a wide strip of land on each side of the railroads soon came to be controlled by nonresident owners. This condition is gradually being changed, but the land far from the railroad is often the most thickly settled, even at the present time.

Farm experience and scientific experiments have built up a system of agriculture which promises to make possible the profitable reoccupation of lands held by nonresidents.

TOPOGRAPHY.

The district is a rolling prairie, bounded on the west by the foothills of the Rocky Mountains and on the east by an imaginary line located somewhere near the one hundredth meridian of longitude. It extends south to the high divide between the Arkansas and Republican Rivers and north to the divide between the Platte and Missouri Rivers. The Platte is the only important river traversing the district, and during the summer months its waters are often reduced to the proportions of a creek. The altitude varies from 3,500 to 5,500 feet. The topography of the section is shown in figure 1.

The water supply is almost entirely from wells. The depth varies from a few feet to several hundred feet. In some localities water has not been located at any depth. New settlers should make sure that a supply of good water is available.

SOIL.

Geologically the district was once part of the bed of a Cretaceous sea. It contains many deposits of marine fossils which add to the natural fertility. The rolling character of the surface is partly due to wind action. Movements due to wind are still in progress, but vegetation retards the action. Many depressions formed by wind have no drainage outlet. The result of the combined forces is a sandy soil, often of considerable depth, very deficient in humus. In a few localities the subsoil is very different from the topsoil. Clay may be found only 1 or 2 feet below the sand. The natural vegetation is an indicator to the experienced eye of the character of the soil;[1] but no examination of land in this district is complete until a few holes have been dug to a depth of 4 or 5 feet. The very sandy lands should not be broken, on account of soil blowing.

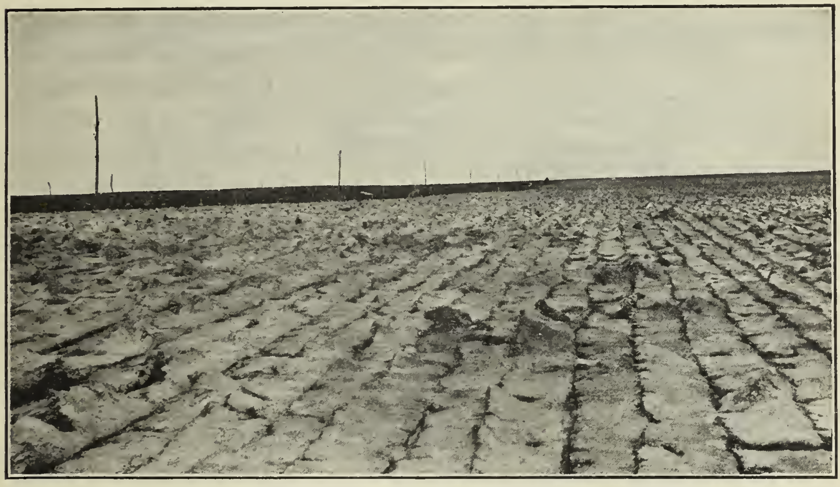

FIG. 1.—Sod broken with a moldboard plow near the Akron Field Station, showing the topography of the locality.

An estimate based on the figures of the Thirteenth Census places the proportion of cultivated land at about 6 per cent of the total area and the proportion in cereals at about 2.5 per cent of the total area.

CLIMATE.

The climate of the district is healthful. The air is dry and is usually in motion. Strong winds are very common, but tornadoes are rare. The winters are generally mild and open, but occasionally snow falls early and remains until spring.

There is a gradual decrease in precipitation from east to west. About two-thirds of the precipitation falls during the growing season,

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[1] Shantz, H. L. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U. S. Dept. Agr., Bur. Plant Indus. Bul. 201, 100 p., 23 fig., 6 pl. 1911.

March to July, inclusive. A more detailed discussion of climatic data recorded at the Akron Field Station follows.

PRECIPITATION.

In general, the precipitation of eastern Colorado decreases as the altitude increases, or from east to west. When the foothills are reached, however, there is a rapid increase in rainfall. The rainfall is also greater on the high divide between the Platte and Arkansas Rivers than at lower elevations to the north or south. In the river valleys the additional precipitation from local showers may considerably affect the total. Local storms of greater or less importance occur every year. They are most common during the summer months. At other times the storm area is usually quite extensive. The limits of the local storms are often very clearly marked. A rainfall of an inch or more may occur at a distance of only 2 or 3 miles from a point where there is no precipitation. Torrential rains are not uncommon, and much damage results from hail.

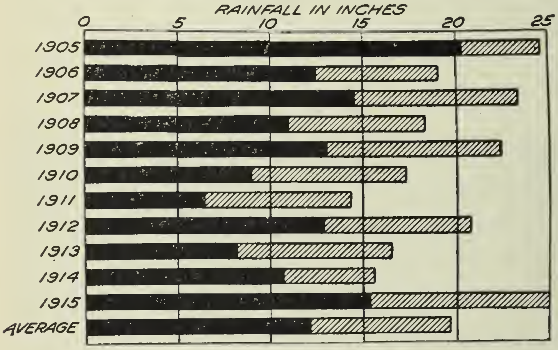

FIG. 2.—Diagram showing the seasonal and annual precipitation at the Akron Field Station for eleven years, 1905 to 1915, inclusive. The solid bars show the seasonal precipitation, while the total length of the bars shows the annual precipitation.

The distribution of precipitation throughout the year is usually favorable to cereal production. The annual and seasonal rainfall at Akron from 1905 to 1915 is shown graphically in figure 2. The annual and average precipitation by months for the 11 years from 1905 to 1915 is given in Table I. The data for the first three years and portions of the fourth and fifth years, as noted, are from the records of the United States Weather Bureau. These observations were made at the town of Akron, which is about 90 feet higher in elevation than the field station and about 4 miles distant. The remaining data are from the records of the Biophysical Laboratory of the Bureau of Plant Industry at the Akron Field Station.

The average precipitation in the 11-year period, 1905 to 1915, inclusive, as shown in Table I, is 19.72 inches. Of this total, 12.33 inches fell during the months from March to July, inclusive, or during the period which most affects the production of the cereals.

TABLE I.—*Monthly, seasonal, and annual precipitation at and near Akron, Colo., during the 11-year period, 1905 to 1915, inclusive.*

[Data (in inches) from the records of the Biophysical Laboratory of the Bureau of Plant Industry, except the following from the records of the United States Weather Bureau at Akron, Colo.: (1) For the years 1905, 1906, and 1907; (2) for January to May, inclusive, and October to December, inclusive, in 1908; (3) for January to March, inclusive, and October to December, inclusive, in 1909. T=trace.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Seasonal.[1]	
														Mar. to July.	Aug. to Oct.[2]
1905	0.37	0.32	5.45	4.55	4.37	2.14	3.82	0.86	0.83	1.73	0.12	0	21.56	20.33	3.42
1906	.25	.26	1.51	4.22	3.32	1.20	2.46	1.26	1.00	1.90	1.56	.08	19.02	12.71	4.16
1907	0	T.	.43	1.74	3.30	3.26	6.06	5.13	1.86	.02	1.00	.60	23.40	14.79	7.01
1908	0	.34	T.	1.70	3.57	2.35	3.40	1.62	.22	3.20	2.00	T.	18.38	11.02	5.04
1909	T.	1.38	3.06	.40	1.87	3.32	4.61	3.77	2.16	.78	.48	.55	22.38	13.26	6.71
1910	.05	.16	.26	3.96	2.06	1.38	1.47	3.72	3.81	.05	.12	.32	17.36	9.13	7.58
1911	.60	.44	.06	2.63	1.15	1.48	1.34	1.30	2.40	1.47	.28	1.36	14.51	6.66	5.17
1912	.28	1.43	.78	2.49	2.86	3.39	3.58	1.58	1.88	1.99	.18	.29	20.73	13.10	5.45
1913	.22	.40	1.57	2.19	1.44	1.35	1.85	1.14	2.08	.34	.30	3.67	16.55	8.40	3.56
1914	.03	.32	.20	4.01	1.46	3.54	1.66	1.05	.23	2.08	.10	.90	15.58	10.87	3.36
1915	1.10	1.68	1.50	5.19	4.13	3.75	1.10	3.51	1.76	.48	.15	.65	25.00	15.67	5.75
Average	.27	.61	1.34	3.00	2.68	2.46	2.85	2.26	1.65	1.27	.57	.76	19.72	12.33	5.20

[1] Months inclusive.

[2] Rainfall affecting the fall growth of winter grains.

TABLE II.—*Monthly and annual precipitation recorded near Leroy, Colo., during the 25-year period, 1891 to 1915, inclusive.*

[Data (in inches) from the records of the United States Weather Bureau at Leroy, Colo. T=trace.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1891	1.70	1.00	1.99	1.35	5.02	4.84	4.69	2.89	0.67	0.14	0.37	0.95	25.61
1892	.89	2.24	.80	4.02	2.53	1.48	3.07	0	.84	1.66	.10	.65	18.28
1893	.05	1.20	.87	.46	2.73	0	1.75	.61	.41	.41	.48	.94	9.91
1894	.35	.46	.95	.98	.17	.75	1.16	.47	1.06	.08	.26	.65	7.34
1895	.73	.88	.40	2.43	2.05	2.94	2.56	.79	.42	.11	.47	.12	13.90
1896	.53	.24	1.20	1.91	2.36	3.77	1.33	.87	.86	.90	.20	.01	14.18
1897	.60	.72	1.66	1.77	3.08	2.24	1.39	2.79	.41	2.61	.40	.81	18.48
1898	.38	.26	.67	1.04	4.60	1.31	2.83	1.13	1.27	.54	.65	.27	14.95
1899	.50	.33	1.21	1.57	2.93	.28	2.17	2.36	.88	.30	.23	.44	13.20
1900	.10	.96	.12	7.27	2.10	.78	1.68	.99	.35	.07	.12	.20	14.74
1901	.06	.49	1.60	2.92	.72	2.52	.97	4.03	.27	.47	T.	.89	14.94
1902	.12	.72	1.23	1.26	3.16	1.82	.98	3.70	3.46	.78	.09	.99	18.33
1903	.18	1.50	.26	1.12	.80	1.07	1.71	3.44	.62	.29	.06	.03	11.08
1904	.10	.26	.35	1.99	3.97	4.39	3.46	1.77	2.96	1.55	.04	.05	20.29
1905	.17	.30	3.28	4.70	3.88	2.48	2.56	1.96	.78	1.93	.12	.02	22.18
1906	.23	.43	1.38	4.53	1.96	1.35	1.88	2.83	2.70	2.69	1.29	.53	21.80
1907	.12	.05	.25	.97	2.85	2.67	2.24	4.19	1.88	T.	.66	.69	16.57
1908	.08	.23	.18	1.68	4.34	3.52	5.72	3.65	.16	3.76	1.86	.05	25.23
1909	.01	1.30	1.80	1.01	1.67	4.15	1.05	2.14	2.81	.56	.91	1.08	18.49
1910	.04	.04	.62	1.96	2.34	2.06	1.53	1.95	1.72	.13	.13	.36	12.88
1911	.32	.24	.10	3.13	1.74	2.21	2.50	1.68	1.16	1.87	.18	.92	16.05
1912	.26	1.16	1.65	2.62	2.58	3.32	1.81	1.60	2.31	2.52	.42	.16	20.41
1913	.21	.96	.77	2.01	2.54	.52	2.96	1.62	1.08	1.17	T.	3.54	17.38
1914	.03	.35	.09	3.45	.78	3.17	2.85	3.54	.04	1.71	.02	.58	16.61
1915	.85	.63	2.09	4.66	4.98	4.45	1.07	5.13	1.63	.62	.24	.76	27.11
Average	.34	.68	1.02	2.43	2.63	2.32	2.23	2.24	1.23	1.07	.37	.63	17.19

The annual precipitation varied from 14.51 inches in 1911 to 25 inches in 1915. The seasonal precipitation varied from 6.66 inches in 1911 to 20.33 inches in 1905. Within the period for which crop records are presented the maximum seasonal precipitation was 15.67

inches in 1915. The seasonal precipitation has been closely correlated with the yield in bushels per acre. The average precipitation, as computed from records of the 11 years, will probably be reduced when the records from a longer series are available. This is evident from the fact that at Leroy, Colo., the 25-year normal precipitation is 17.19 inches (Table II). Leroy is located about 30 miles northeast of the Akron Field Station and is subject to similar climatic influences. The average precipitation during the 11-year period, 1905 to 1915, is 19.51 inches at Leroy and 19.72 inches at the Akron Field Station.

A droughty condition often prevails from about June 15 to August 31. The precipitation which falls during this period usually comes in the form of light showers. As the temperatures are high during the summer months, this precipitation is rapidly lost by evaporation. Table III, which gives the daily precipitation record at the Akron Field Station for 1914, illustrates this point. This table shows that from June 15 to October 8 there were only two rains of more than 0.25 inch.

TABLE III.—*Daily precipitation recorded at the Akron Field Station, Akron, Colo., for the year 1914.*

[Data (in inches) from the records of the Biophysical Laboratory of the Bureau of Plant Industry. T=trace.]

1914	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1					0.25	0.81						
2				0.20			0.02					
3								T.		0.17		
4			T.			.04	T.	T.		T.		
5		0.02		T.	T.							
6				.12			.03		0.07	T.		0.10
7				T.		T.			T.	T.		.40
8									.08	.26		.10
9	0.03		T.	.16					.02	.14		.10
10								T.				
11					.10	.07						
12						.11	T.					
13					.90	.26		0.01	.06			
14						2 24	T.					
15					.13	T.						
16				.46	.03		T.		T.		0.10	
17				.27	T.		.47	.10				
18			T.	T.	T.		.23	.25				
19			T.				T.	.03				
20						.01		.04	T.			
21							T.			.06		.20
22		.30		.02	T.		T.			.49		
23				.87				.02		.96		
24			T.	T.		T.		.14				
25							T.	.22				
26				.35			.17	.22				
27				T.	.05		.01					
28			0.20	T.	T.		.08					
29			T.	.49			T.					
30			T.	1.07		T.	.65	.02				
31					T.			T.				
Total	.03	.32	.20	4.01	1.46	3.54	1.66	1.05	.23	2.08	.10	.90

EVAPORATION.

As a factor affecting crop production the seasonal evaporation probably ranks next in importance to precipitation at the Akron Field Station. The total evaporation from a free water surface for each month from April to September, inclusive, in the 8-year period, 1908 to 1915, is given in Table IV. The precipitation for the same period is included, and the ratio of precipitation to evaporation each year is also given. The data show that evaporation from the free water surface increases when precipitation decreases, but not in exact ratio. The highest evaporation was recorded in 1911, but the lowest precipitation occurred in 1913. The year of lowest evaporation was 1915, which was also the year of highest precipitation. The ratio of precipitation to evaporation over the total period for which records are available is 1 to 2.9.

TABLE IV.—*Monthly precipitation and evaporation from a free water surface at the Akron Field Station, Akron, Colo., from April to September of each year, 1908 to 1915, inclusive.*

[Data (in inches) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	April.		May.		June.		July.		August.		September.		Total.		Ratio.
	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	Precipitation.	Evaporation.	
1908	1.70	4.740	3.57	7.709	2.35	8.637	3.40	8.474	1.62	7.826	0.22	8.550	12.86	45.936	1:3.5
1909	.40	4.734	1.87	6.825	3.32	7.003	4.61	9.396	3.77	8.538	2.16	5.857	16.13	42 353	1:2.6
1910	3.96	6.387	2.06	5.797	1.38	8.722	1.47	9.763	3.72	7.142	3.81	5.810	16.40	43.621	1:2.6
1911	2.63	5.841	1.15	7.323	1.48	9.753	1.34	9.774	1.30	8.944	2.40	7.183	10.30	48.818	1:4.8
1912	2.49	4.576	2.86	7.097	3.39	6.750	3.58	7.618	1.58	7.048	1.88	4.648	15.78	37.737	1:2.3
1913	2.19	4.336	1.44	5.835	1.35	8.178	1.85	9.259	1.14	9.302	2.08	6.040	10.05	42.950	1:4.2
1914	4.01	4.290	1.46	5.608	3.54	7.509	1.66	8.654	1.05	8.364	.23	7.438	11.95	41.863	1:3.5
1915	5.19	4.220	4.13	5.033	3.75	5.883	1.10	6.660	3.5	5.820	1.76	5.793	19.44	33.409	1:1.7
Average	2.82	4.890	2.32	6.403	2.57	7.804	2.37	8.699	2.21	7.873	1.82	6.415	14.11	42.084	1:2.9

The precipitation and evaporation in the months of August and September are less important in the production of spring-sown cereals than in the production of those sown in the fall. The germination of winter wheat is often slow and sometimes very poor, due to the scarcity of moisture in the seed bed at the time of sowing. Crop growth and surface evaporation may have exhausted the moisture from the surface below the seeding depth, even though the lower levels contain sufficient moisture to maintain plant growth.

Very low humidity of the atmosphere, rapid transpiration from growing plants, and high wind velocity are responsible for the rapid and often premature ripening of cereals. For this reason the early-maturing varieties in each group usually produce a higher quality of grain than the later ones. The growth of all is checked at about the same time.

WIND.

Wind is an important element of the climatic influences in this section of the Great Plains. Records of wind velocity have been made during the summer months since 1908 and during the entire year since 1912. The available records for the 8-year period, 1908 to 1915, inclusive, as given in Table V, show an average wind velocity of 6.9 miles per hour. The months of April and May have average wind velocities higher than any of the other months. The highest wind velocity for any one month is 10.3 miles per hour, in May, 1909. The lowest wind velocity was recorded in August, 1915. The prevailing winds at the Akron Field Station are from the southwest during the summer and from the northwest during the winter.

TABLE V.—*Average wind velocity at the Akron Field Station, Akron, Colo., by months, 1908 to 1915, inclusive, as far as data are available.*

[Data (in miles per hour) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
1908	......	......	......	......	......	8.0	6.0	6.7	7.6	......	......	......	......
1909	......	......	......	9.0	10.3	6.8	6.8	5.8	6.7	......	......	......	......
1910	......	......	......	......	8.1	8.6	6.1	5.0	6.0	7.1	5.1	6.3	......
1911	6.2	6.5	8.7	9.1	9.7	7.4	7.1	8.1	7.0	......	......	......	......
1912	6.7	7.5	7.8	9.9	8.5	6.1	5.4	4.7	6.0	6.1	5.7	6.3	6.7
1913	6.2	4.9	6.6	8.1	6.9	8.1	6.1	5.6	6.4	7.1	5.1	8.5	6.6
1914	8.2	6.6	8.5	8.7	7.4	5.8	5.8	6.5	6.9	6.4	6.2	5.8	6.9
1915	8.0	6.5	7.3	7.5	7.7	6.8	6.2	4.3	6.4	5.7	7.9	6.0	6.7
Average	7.0	6.4	7.7	8.7	8.3	7.2	6.2	5.8	6.6	6.9	6.0	6.6	6.7

TEMPERATURE.

The temperatures at the Akron Field Station are recorded by means of maximum and minimum dry-bulb thermometers, supplemented by a thermograph during the growing season. A summary of the recorded data is given in Table VI. The records are complete for the six months from April to September, inclusive, for the 8-year period, 1908 to 1915. Sufficient data are available for other months during a portion of this period to form a good basis for study.

The month of August has the highest average maximum temperature, 85° F. December and January have the lowest average minimum, 13° F. The highest maximum for any one month is 90° F., recorded for July, 1910. Temperatures of 100° F. are not uncommon during July and August. The combination of high winds and high temperatures with only light showers usually causes a droughty condition to prevail from about June 15 to August 31, as noted in the discussion of precipitation.

TABLE VI.—*Mean, maximum, and minimum temperatures at the Akron Field Station, Akron, Colo., by months, 1908 to 1915, inclusive, so far as data are available.*

[Data (in ° F.) from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Year.	January.			February.			March.			April.			May.			June.		
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.
1908	....	....	....	....	....	....	....	....	....	51	70	32	55	71	40	64	79	49
1909	....	....	....	....	....	....	....	....	....	42	56	29	52	68	39	64	79	52
1910	....	....	....	....	....	....	....	....	....	50	65	35	53	66	40	67	82	51
1911	33	48	17	28	42	14	43	60	26	47	62	31	58	73	43	70	87	53
1912	20	32	8	26	36	16	20	29	11	45	58	32	55	70	42	63	75	49
1913	24	37	10	18	29	7	34	47	21	47	63	33	57	72	44	67	82	53
1914	31	42	21	25	39	12	37	52	23	45	58	34	57	70	44	68	83	50
1915	22	33	11	32	42	22	29	39	19	50	62	38	52	64	41	60	72	49
Average	26	38	13	25	37	14	32	45	20	47	61	33	55	69	41	65	79	50

Year.	July.			August.			September.			October.			November.			December.		
	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.
1908	70	84	55	69	84	54	66	84	48	....	....	....	....	....	....	....	....	....
1909	71	86	59	72	88	59	60	76	47	....	....	....	....	....	....	....	....	....
1910	74	90	59	67	84	54	63	79	49	52	71	35	40	56	24	31	47	17
1911	70	86	55	69	86	54	64	80	50	....	....	....	....	....	....	....	....	....
1912	70	84	55	69	83	55	54	68	41	47	63	34	40	55	25	29	....	14
1913	72	88	55	75	91	59	58	70	45	45	59	31	42	56	28	21	30	13
1914	72	87	58	71	88	55	64	83	47	50	67	36	41	60	25	17	29	7
1915	67	81	54	64	79	52	60	76	47	51	69	36	38	55	24	28	40	15
Average	71	73	56	69	85	55	61	77	46	49	65	34	40	56	25	25	36	13

Table VII gives the dates of the last spring and the first fall frosts and the number of days in the frost-free period of each year from 1909 to 1915, inclusive. The latest date on which frost has occurred in the spring during the seven years was May 20, and the average date is May 13. The earliest frost in the fall was September 13, and the average date is September 26. A temperature low enough to cause some injury occurred on August 25, 1910.

TABLE VII.—*Annual and average dates of killing frosts,*[1] *the last in spring and the first in autumn, with the annual and average length of the frost-free period, at the Akron Field Station, Akron, Colo., 1909 to 1915, inclusive.*

[Data from the records of the Biophysical Laboratory of the Bureau of Plant Industry.]

Item.	1909	1910	1911	1912	1913	1914	1915	Average.
Frost:								
Last in spring	May 14	May 21	May 10	May 14	May 4	May 12	May 20	May 13
First in fall	[2] Oct. 9	Sept. 25	Oct. 3	Sept. 20	Sept. 24	Sept. 13	Oct. 4	Sept. 26
Frost-free period, days	148	127	146	129	143	124	137	136

[1] A temperature of 32° F. is considered frost in the spring when vegetation is tender and a temperature below 32° F. is considered frost in the fall.

[2] Record from Leroy, Colo.

THE AKRON FIELD STATION.

The following paragraphs contain a description of the Akron Field Station, the scope of the experiments, and the methods employed in conducting them.

LOCATION.

The Akron Field Station is located 4 miles east of Akron, the county seat of Washington County, in northeastern Colorado. It is about 60 miles south of the Nebraska line and 60 miles west and 11 miles north of the point where Colorado meets the north line of Kansas. The Chicago, Burlington, & Quincy Railroad bounds the station on the south. Denver lies about 115 miles southwest. The station is located in approximately 40° N. latitude and 130° W. longitude. The elevation is about 4,560 feet above sea level.

DESCRIPTION.

The Akron Field Station contains 227 acres. Of this area, 160 acres, known as the "forestry quarter," are owned by the Colorado Agricultural Experiment Station and are used by the Bureau of Plant Industry of the United States Department of Agriculture in accordance with the terms of a cooperative agreement. The legal description of this land is the "NE. $\frac{1}{4}$ section 12, township 2 N., range 52 W." Sixty-seven acres lying directly south of the forestry quarter are controlled by the Department of Agriculture through the Office of Dry-Land Agriculture Investigations. The buildings at the station are shown in figure 3.

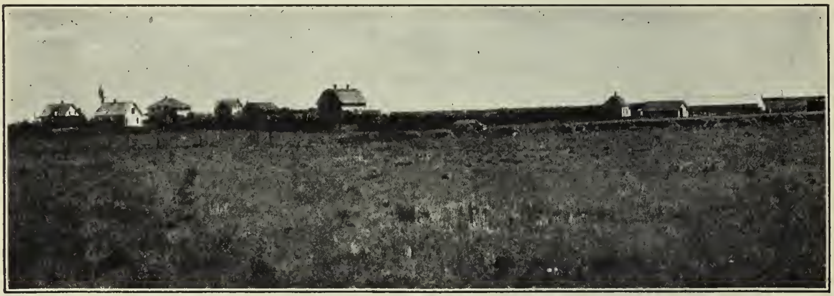

FIG. 3.—Buildings of the Akron Field Station. Native vegetation is shown in the foreground. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

The surface of the farm ranges from nearly level to slightly rolling. Very little moisture is lost by run-off. There are no protecting hills or effective shelter belts. No part of the experimental area is irrigated.

The soil is a fine sandy loam. Various local names, such as "hard land" or "tight land," are given this type of soil to distinguish it from the light, sandy soils. The dark surface layer varies from 1 to 2 feet in depth, below which the soil is light in color, due to lack of organic matter. Very little coarse gravel is present to interfere with root penetration. There is no impervious layer near enough to the surface to affect root development or water movements.

Plowing and other tillage operations are easily performed when the soil is moist but become very difficult when the moisture content is low. The fine soil particles are readily blown by the wind when surface conditions are favorable.

There is considerable variation in the soil that has been used in plat tests. Yields of the same variety on plats differently located but uniformly treated have varied from 3 to 5 bushels per acre. The experimental error that results from these variations is somewhat reduced by the shifting of plat locations from year to year. Replicated plats were used in 1915. For varieties used as checks in previous years the average yield of all plats is recorded in this bulletin.

SCOPE OF THE EXPERIMENTS.

More than 11,000 tests have been conducted during the eight years covered by this report. Of this total, 10 per cent was in field plats and 90 per cent in nursery rows. Varietal tests have been made each year. Tests of rates and dates of seeding were begun in 1911.

The number of tests has varied from year to year. In 1908 there were 315 nursery rows and 80 field plats. The number of field plats gradually increased to 185 in 1915. The number of nursery rows was increased to 2,200 in 1910 and since that time has averaged 1,187. The field-plat tests have included varietal tests of winter wheat, emmer, and rye, and of spring wheat, oats, barley, flax, proso, and grain sorghums. There have also been rate-of-seeding tests with winter wheat, spring wheat, and spring oats, and date-of-seeding tests with winter wheat.

EXPERIMENTAL METHODS.

The experiments with cereals at the Akron Field Station have been conducted in field plats and in nursery rows. Varietal tests, rate-of-seeding tests, and date-of-seeding tests have been conducted on field plats.

SIZE OF PLATS.

Most of the experiments have been conducted on tenth-acre plats. These plats are 2 rods wide by 8 rods long. They are laid out side by side in series, the plats being separated by alleys 4.62 feet wide. The different series are separated by roads 19.67 feet wide. Vegetation in the roads is controlled by frequent clipping with a mowing machine or by the use of a road grader which kills all weeds.

Throughout the period of the test it has been necessary to subdivide the tenth-acre units in at least a portion of the series in order to make sufficient divisions for all of the work being done. The subdivisions have usually been twentieth-acre plats, formed by making a 16-inch alley between the subdivisions and reducing the width of the alley between tenth-acre plats. Smaller plats are used when sufficient seed is not available to sow the standard plat. Usually no plats smaller than 0.01 acre in size are classed as field plats, but in a few instances plats containing 0.008 acre have been called field plats. Nursery rows have been used for the preliminary tests, and many varieties tested in the nursery have proved so poorly adapted to conditions that they were never grown in the field plats. Careful agronomic and physiologic observations have been made and are preserved in the form of annual reports.

REPLICATION OF PLATS.

Until 1915 only one plat of each variety was grown each year, but a leading variety of each cereal was used as a check. Usually there were five or more check plats from which the data could be averaged. In 1915 all of the leading varieties were sown in duplicate twentieth-acre plats. The value of repeating all the varieties in the experiment is apparent, and mcre extensive replication is planned for the future.

SOIL TREATMENT.

In preparing the land for experimental tests the aim has been to conform as closely to farm practice as possible. The plowing has been done at the moderate depth of 5 to 7 inches, and subsequent treatment has been in accord with common farm practice. The cultivation has been limited to that required to control weed growth.

Most of the experimental work has been conducted on land summer-fallowed the previous year. This was done to keep the land uniform and to assist in the control of weed growth. When the experiments were begun, summer fallowing was thought to be the most profitable method of production. In 1914 the spring-wheat varieties were grown on land which had been cropped to corn the previous year. Oats have been grown following potatoes or fallow.

The usual practice in summer fallowing has been to plow in the spring and pack with the disk harrow. Weeds were kept in check during the summer by two or three subsequent diskings. Usually the last treatment immediately preceded the sowing of the grain, either in the fall or the spring.

Rate-of-seeding and date-of-seeding tests were included in the same series of plats as the varietal work and were on land receiving the same soil treatment.

RATES AND DATES OF SEEDING.

The rate of seeding for wheat, oat, and barley varieties was 4 pecks per acre in the first year, 1908. Since 1908 the rate of seeding for wheat has been 3 pecks per acre. Barley was sown at the rate of 3 pecks per acre in 1909 and 1910, and for the remaining time at the rate of 4 pecks per acre. The rate of seeding for oats was 3 pecks per acre from 1909 to 1912. In 1913 the rate for oats was increased to 4 pecks, which was continued in 1914 and 1915. The date of seeding has varied with seasonal conditions. Table VIII gives the dates of sowing for each of the more important cereals in the 8-year period, 1908 to 1915, inclusive. Spring grains have been sown as early as the seed bed could be put in condition to receive the seed.

Table VIII.—*Dates on which varieties of winter wheat, spring wheat, spring oats, and spring barley have been sown in each of the eight years, 1908 to 1915, inclusive, at the Akron Field Station, Akron, Colo.*

Crop year.	Cereal group.			
	Winter wheat.	Spring wheat.	Spring oats.	Spring barley.
1908	Nov. 5	Apr. 12	Apr. 12	Apr. 12
1909	Sept. 23	Apr. 26	Apr. 26	Apr. 25
1910	Sept. 27	Mar. 18	Mar. 19	Mar. 31
1911	Sept. 6	Mar. 16	Mar. 17	Apr. 7
1912	Sept. 11	Apr. 11	Apr. 16	Apr. 15
1913	Sept. 30	Apr. 5	Apr. 17	Apr. 18
1914	Sept. 26	Mar. 24	Mar. 30	Mar. 31
1915	Sept. 16	Apr. 14	Apr. 17	Apr. 19

NURSERY EXPERIMENTS.

The nursery tests at Akron have included newly introduced varieties and those of which there was not sufficient seed for sowing in field plats and also pure-line selections from the better varieties. The tests of selections have been the largest feature of the nursery work. The varieties and selections have been grown in short rows, usually from 5 to 25 feet in length. It is possible in the nursery to test economically a very much larger number of varieties and strains than could have been included in field-plat tests.

Over 250 separate named or numbered varieties of cereals have been grown in nursery rows. Wherever the performance was such as to indicate a possible superior or promising variety it was increased for further tests in field plats. The greater portion of the varieties tested proved inferior and have been discarded. A few are now being grown in field plats.

Much more work has been done in an attempt to isolate superior races from varieties. A large number of heads were selected from plants in the field plats. The following season the grains from each head were sown in a short nursery row called a head row. Notes were taken during the growing season, and the more promising races were grown the following season in longer rows. In the longer rows the race was checked against the parent variety or some other variety used as the standard. After one or two seasons' test, all those that failed to excel the check were discarded. Several hundred selections have been tested in this way.

At first it was thought that further improvement might result from selection within pure lines. Several hundred selections were made, but no superior races have been isolated and the practice has been discontinued.

Races that proved superior in nursery rows were sown in increase plats in order to get seed for advancing the test to field plats. A few of the races thus isolated now rank with the best varieties in their respective groups.

INTERPRETATION OF EXPERIMENTAL RESULTS.

The best variety or method of culture is the one which on the average will produce the highest acre value at the least cost. None of the varieties or methods of culture tested have fulfilled all these requirements for each of the years tested. Some varieties have held secondary positions for two or three years, and yet in the average for the 8-year period they rank among the first. The best variety or method, presumably, is that one which gives the best average during a series of years, provided the seasons are representative. In actual practice, however, the problem is more complicated than would appear from this statement. The variation in soil from place to place, the changes in climatic factors from year to year, and especially at critical times during the period of cereal growth, and the adaptability of the different varieties to the changing conditions must all be taken into account.

EXPERIMENTS WITH WHEAT.

Experiments with wheat at the Akron Field Station have included plat and nursery tests of both winter and spring varieties. In addition to varietal tests there have been date-of-seeding and rate-of-seeding experiments with winter wheat and rate-of-seeding experiments with spring wheat.

Wheat has occupied a major position in the cereal tests. It is the cash crop of the district. Its acre value is equal to or greater than that of other cereals, and there is always a market for the grain. Considerable time has been devoted to developing improved strains. Two or three of the hundreds of selections made are proving superior to the parent stocks. The work of first importance, however, has been the testing of varieties.

WINTER WHEAT.

Winter wheat has been more profitable in this section than spring wheat. The most important varieties are the hard red winter wheats belonging to the Crimean or Turkey group. Six varieties have been grown continuously since the Akron Field Station was established in 1907. Rate-of-seeding and date-of-seeding experiments were started in 1911. Kharkof is the variety that has been used in these tests. An excellent field of winter wheat in the vicinity of the station is shown in figure 4.

VARIETAL EXPERIMENTS.

Experiments with winter wheat have been conducted both on field plats and in the nursery. These will be discussed separately.

PLAT EXPERIMENTS.

The winter-wheat varieties have been sown each year on land prepared by clean summer fallow. The date of seeding has varied because of weather conditions. Table VIII gives the dates on which sowing commenced each year. Except in the fall of 1907, the sowing has been done in September. The rate of seeding was 4 pecks per acre in 1907 and 3 pecks per acre in the following years. No fixed depth of seeding has been used. The object has been to sow the seed in moist soil, and in dry seasons this means 2 or 3 inches below the surface. Table IX shows the annual and average yields of 17 varieties of winter wheat grown at the Akron Field Station within the 8-year period, 1908 to 1915, inclusive.

FIG. 4.—Winter wheat in shock on a farm in the vicinity of the Akron Field Station, 1912.

In the fall of 1907 the winter-wheat varieties were sown on land which had been broken the previous summer. Although the seed was sown late (Nov. 5), a good stand was obtained, and the varieties adapted to this part of the Plains gave fair yields. A number of varieties which failed completely are not included in Table IX.

In the fall of 1908 the seed was treated with formaldehyde solution for smut. The germination was slow. Counts for stand were not made in the fall, but some plats were recorded as having good stands. The causes for the failure shown by zero yields in 1909 are not apparent. The formaldehyde treatment was charged with the failure at the time, but winterkilling was more probably the cause. Enough seed was obtained from most of the varieties for resowing. The crop was not sufficiently large, however, to pay the cost of harvesting, and for that reason the yields are recorded as zero. This year is included in calculating the average yields.

TABLE IX.—*Annual and average yields of 17 varieties of winter wheat grown at the Akron Field Station, Akron, Colo., in the 8-year period, 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).									
		1908	1909	1910	1911	1912	1913	1914	1915	Average. All years grown.	Average. Six years, 1910 to 1915.
Crimean:											
Alberta Red	2979	21.1	0	......	12.5	......	17.8	31.1	31.3	19.0	....
Beloglina	1543	......	0	23.6	......	......	12.5	24.5	18.4	19.8	....
Crimean	1432	19.2	......	......	......	......	......	......	......	....	....
Do	1436	19.1	0	38.3	17.9	33.1	12.6	28.3	26.6	22.0	26.1
Do	1437	14.6	0	34.8	13.3	32.5	14.0	25.3	26.6	20.2	24.3
Do	1559	......	......	36.9	11.5	32.7	17.0	39.6	29.0	27.8	27.8
Kharkof	1442	20.6	0	27.9	10.0	34.3	16.1	26.6	27.5	20.4	23.7
Do	1583	19.3	0	29.8	14.2	37.5	16.6	25.9	29.2	21.6	25.5
Kharkof, 6 P4	4207	......	......	......	10.3	33.2	18.5	26.1	28.3	23.3	....
Malakof	2908	......	......	26.8	17.3	35.4	18.1	30.1	30.5	26.4	26.4
Torgova	1539	......	......	20.6	......	......	......	......	......	20.6	....
Turkey	1558	15.8	......	......	......	......	......	......	......	....	....
Do	1571	19.8	0	29.5	11.5	43.2	7.3	25.1	28.1	20.6	24.1
Do	2998	......	......	......	......	28.8	6.8	25.0	23.3	21.0	....
Miscellaneous:											
Buffum No. 17	3330	......	......	......	......	17.5	6.5	13.8	26.6	16.1	....
Diehl Mediterranean	1395	10.4	0	37.1	8.9	......	12.8	30.5	26.4	18.0	....
Ghirka Winter	1438	15.6	0	38.5	15.8	38.3	17.3	24.0	22.8	21.5	26.1

The yields in 1910 were high, due to the favorable distribution of precipitation. In 1911 a lack of moisture caused the lowest yields of any of the years for which yields are recorded. The average yield of all varieties of the Crimean group in 1911 was 12.7 bushels per acre.

The year 1912 again gave high yields, the average for the Crimean group being 34.5 bushels per acre. This is 4 bushels more than the next highest yield, 30.5 bushels per acre, produced in 1910.

The crops of 1914 and 1915 were only of ordinary size. It is well to note that the yield of grain was not increased in proportion to the increased rainfall of the year 1915. This is due to unfavorable distribution, which resulted in a lack of moisture during ripening.

Six varieties have been tested during the 8-year period. Of these, Crimean (C. I. No. 1436) has given an average yield of 22 bushels per acre. The second in rank is Kharkof (C. I. No. 1583), with an average yield of 21.6 bushels. In 1910 two varieties of promise were introduced. These are Crimean (C. I. No. 1559) and Malakof (C. I. No. 2908). In the six years they have been grown these two varieties have given higher average yields than any of the others. Ghirka Winter (C. I. No. 1438) and Crimean (C. I. No. 1436) have tied for third place in the 6-year period.

In Table X agronomic data are given for five varieties which have been grown during the 8-year period. These data include average dates of heading and ripening, height, weight per bushel, and yield of grain. There is very slight difference shown in the average dates of heading and ripening, but there is a difference in the average length of straw, Ghirka Winter (C. I. No. 1438) having an average height of 39 inches and Crimean (C. I. No. 1436) an average height of 32 inches. The difference in weight per bushel is slight.

TABLE X.—*Average dates of heading and ripening, height, weight per bushel, and yield per acre of five leading varieties of winter wheat grown at the Akron Field Station, Akron, Colo., during the 8-year period, 1908 to 1915, inclusive.*

Variety.	C. I. No.	Average date— Headed.	Average date— Ripe.	Height.	Weight per bushel.	Yield per acre.
				Inches.	*Pounds.*	*Bushels.*
Crimean	1436	June 18	July 13	32	58.4	22.0
Kharkof	1583	June 17	July 14	35	58.3	21.6
Ghirka Winter	1438	June 18	July 16	39	58.8	21.5
Turkey	1571	June 17	July 15	35	58.2	20.6
Kharkof	1442	...do.....	July 14	35	58.3	20.4

NURSERY EXPERIMENTS.

The cereal nursery has made possible the testing of a large number of varieties and strains. Sixty-three varieties have been tested in nursery rows, most of which have not shown sufficient promise to warrant advancing them to field tests. A much larger number of pure-line selections have been tested in the nursery and most of them discarded. One of the strains has been increased and is worthy of mention. It is a selection of Kharkof (C. I. No. 1442) and has been designated Kharkof 6P4 (C. I. No. 4207).

Nursery sowings have suffered from soil blowing to such an extent that the results are not entirely comparable. In 1914 several rows were almost entirely killed. Soil blowing follows as a consequence of the special soil preparation necessary in order to sow by hand or with garden tools. In order to prevent soil blowing it is necessary to have an uneven and, if possible, a lumpy surface.

RATE-OF-SEEDING EXPERIMENTS.

Rate-of-seeding tests of Kharkof winter wheat have been conducted at Akron for five years. During that time four rates of seeding have been used each year. The seed has been sown on summer-fallowed land at the same time as the varietal tests. The results are shown in Table XI.

TABLE XI.—*Annual and average yields of Kharkof winter wheat in a rate-of-seeding test at the Akron Field Station, Akron, Colo., 1911 to 1915, inclusive.*

Rate of seeding per acre.	Yield per acre (bushels).					
	1911	1912	1913	1914	1915[a]	Average.
2 pecks	9.6	38.0	18.3	18.3	30.5	23.1
3 pecks	10.4	44.0	15.3	24.0	33.0	25.3
4 pecks	12.8	39.3	16.3	24.3	32.5	25.0
5 pecks	13.8	38.3	18.6	37.3	34.2	28.4
6 pecks	....	....	18.6	27.3	34.5	26.6

[a] Average of two varieties, Crimean (C. I. No. 1559) and Kharkof (C. I. No. 4207).

The results recorded in Table XI are not satisfactory or conclusive. It is thought that soil variations have interfered with the test to some extent. The maximum yield has varied from one rate to another as the seasons have varied. More data are needed before conclusions can be drawn. It will be noted that the 4-peck rate gave an average yield less than either the 3-peck or the 5-peck rate. The 5-peck rate gave the highest average yield. This rate produced the best yield in 1911, when there was a scarcity of moisture, and in 1915, when moisture was plentiful. In 1912, however, the 3-peck rate gave a yield 4.2 bushels higher than the 4-peck rate and 5.2 bushels more than the 5-peck rate. During the last three years a 6-peck rate has been included. The average shows a slight decrease in yield as compared with the lighter seedings. At present the data are contrary to what farmers believe to be the best rate to sow to obtain maximum yields.

DATE-OF-SEEDING EXPERIMENTS.

An experiment to determine the best date to sow winter wheat was begun in 1911. In 1912 the test was not conducted, on account of the dry condition of the seed bed at the time of sowing. It has not been possible to sow on the same date each year and therefore the time has been divided into 15-day periods. The test has been made on summer fallow. The rate of seeding has been 3 pecks per acre. It has been difficult to make sowings earlier than September 15 and snow and frost usually prevent seeding after November.

The annual and average yields obtained in this test during four years, 1911, 1913, 1914, and 1915, are given in Table XII. The experiment has not been conducted long enough to establish any fact, but the figures indicate that the best time to sow winter wheat to get maximum yields is between September 15 and October 15.

Table XII.—*Annual and average yields of Kharof winter wheat in a date-of-seeding test at the Akron Field Station, Akron, Colo., in 1911, 1913, 1914, and 1915.*

Date of seeding.	Yield per acre (bushels).				
	1911	1913	1914	1915	Average.
Sept. 16 to 30, inclusive	15.5	15.6	26.0	27.3	21.1
Oct. 1 to 15, inclusive	16.1	15.6	26.6	34.2	23.1
Oct. 16 to 31, inclusive	....	12.6	11.3	25.8	[a]16.6
Nov. 1 to 30, inclusive	16.5	8.6	13.6	26.6	15.1

[a] Three-year average.

The sowings made during the first 15 days in October have given yields as high as or higher than those from any other date of seeding during the last three years of the test. In 1911 an early sowing (Sept. 6) gave the highest yield, 16.8 bushels, and a late sowing (Nov. 11) ranked second. The average of the yields from sowings made between September 15 and October 15 is 22.1 bushels, which is 5.5 bushels higher than the yield from sowings made during the following 15-day period.

SPRING WHEAT.[1]

Spring wheat is an important crop in this section of the Great Plains. It can be sown early on land prepared during the late fall. It has given good yields when conditions were favorable. The varieties which have given the highest yields are durum wheats. In addition to the varietal experiments, a rate-of-seeding test has been conducted with Arnautka durum wheat since 1911.

VARIETAL EXPERIMENTS.

Experiments with spring wheat have been conducted both on field plats and in the nursery. These will be discussed separately.

PLAT EXPERIMENTS.

A total of 44 varieties of spring wheat have been grown in field plats for one year or more. Table XIII shows the annual and average yields of these varieties, arranged in groups according to their relationships.

Seven varieties of durum wheat have been grown continuously during the eight years. Pelissier (C. I. No. 1584) has given the highest average yield, 22.4 bushels per acre. Velvet Don (C. I. No. 1445) ranks second, and Arnautka (C. I. No. 1493) is third. The fourth variety in rank is the Galgalos (C. I. No. 2398), a soft white common wheat which belongs to none of the groups grown commercially. Arnautka 6P1 (C. I. No. 4064) has given an average yield of 27.6 bushels per acre for the six years in which it has been grown.

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[1] For a discussion of the groups and varieties of hard spring wheat, see Ball, C. R., and Clark, J. A., Varieties of hard spring wheat. U. S. Dept. Agr., Farmers' Bul. 680, 20 p., 7 fig. 1915.

It is a selection from Arnautka (C. I. No. 1494). If the data for the parent variety and the selection are combined, the average yield in the 8-year period is 24.5 bushels, which would give it first rank. At the present time the difference in yield in favor of any one variety is not sufficient to be conclusive. A plat of durum wheat at the station is shown in figure 5.

TABLE XIII.—*Annual and average yields of 44 varieties of spring wheat grown at the Akron Field Station, Akron, Colo., in the eight years, 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).									
		1908	1909	1910	1911	1912	1913	1914	1915	Average. All years grown.	Average. 8-year period.
DURUM WHEATS.											
Kubanka:											
Arnautka	1493	26.9	20.8	16.6	10.6	27.5	10.5	27.6	27.9	21.1	21.1
Do	1494	18.7	11.8	......	......	......	......	......	......	15.3	....
Do	1547	19.0	......	......	......	......	......	......	......	......	....
Arnautka 6P1	4064	......	......	19.5	15.7	37.3	10.6	25.0	27.6	27.6	....
Beloturka	1520	31.1	19.4	19.9	8.0	21.1	10.6	19.5	26.7	19.5	19.5
Gharnovka	1447	29.1	20.9	[a]13.1	9.3	36.5	3.3	27.7	22.2	20.3	20.3
Kubanka	1354	27.2	18.0	21.3	11.7	19.8	13.6	22.7	......	19.2	....
Do	1440	26.8	9.3	17.1	9.0	25.1	5.1	20.7	27.6	17.6	17.6
Do	1516	......	......	......	9.1	30.0	6.0	26.5	31.3	20.6	....
Do	2246	14.8	......	......	......	......	......	......	......	......	....
Do	2882	13.9	......	......	......	......	......	......	......	......	....
Marouani	1593	22.9	14.2	19.3	10.6	19.0	14.1	24.0	......	17.7	....
Pererodka	1350	29.2	15.9	11.5	......	......	......	......	......	18.8	....
Taganrog	1570	20.0	......	......	......	......	......	......	......	......	....
Pelissier:											
Pelissier	1584	24.7	23.6	15.8	10.6	35.6	10.5	26.6	31.6	22.4	22.4
Velvet Don:											
Velvet Don	1445	33.3	21.1	13.5	10.0	33.3	7.3	25.3	28.1	21.5	21.5
Kahla:											
Bledur	1471	15.4	16.8	17.7	10.6	33.0	8.3	26.3	33.6	20.2	20.2
Purple	3024	24.8	20.8	15.3	7.9	33.0	10.0	21.2	......	19.0	....
Miscellaneous:											
Adjini	2941	19.5	12.3	......	......	......	......	......	......	15.9	....
Medeah	1597	17.8	13.7	......	......	......	......	......	......	15.8	....
COMMON WHEATS.											
Fife:											
Cole Hybrid	4062	11.8	27.9	21.5	12.3	18.2	8.0	21.0	......	17.2	....
Ghirka	1517	20.6	23.8	18.8	8.5	23.3	11.6	19.3	22.6	18.6	18.6
Glyndon (Minn. No. 163)	2873	......	......	......	9.4	17.3	8.0	16.6	16.2	13.5	....
Marquis	3641	......	......	......	......	......	7.5	19.7	26.5	17.9	....
Power	3025	22.5	......	......	......	......	......	......	......	......	....
Rysting	3022	19.3	......	......	......	......	......	......	......	......	....
Bluestem:											
Bolton	3023	20.4	......	......	......	......	......	......	......	......	....
Haynes (Minn. No. 169)	2874	......	......	......	......	......	......	......	16.4	......	....
Do	3020	25.2	15.3	19.8	......	......	......	......	......	20.1	....
Haynes (Minn. No. 51)	3021	24.0	......	......	......	......	......	......	......	......	....
Preston:											
Erivan	2397	19.3	26.3	15.2	11.9	20.7	12.0	19.3	19.5	18.0	18.0
Fretes	1596	10.3	......	......	......	......	......	......	......	......	....
Pioneer	4324	......	......	......	......	......	......	......	28.7	......	....
Preston	3081	......	......	......	......	......	......	......	26.2	......	....
Do	3087	9.6	18.3	......	......	......	......	......	......	14.0	....
Red Russian	4141	......	15.2	15.6	12.1	23.2	8.3	23.0	23.9	15.2	....
Miscellaneous:											
Galgalos	2398	21.8	19.8	20.5	19.6	20.5	14.1	21.7	24.4	20.3	20.3
Manchuria	2492	18.2	23.3	[b]25.0	......	......	......	......	21.2	21.9	....
Mexican No. 1	3035	7.5	......	......	......	......	......	......	......	......	....
Prelude	4323	......	......	......	......	......	......	......	29.5	......	....
Rieti	2942	3.0	......	......	......	......	......	......	......	......	....
Sonora	1946	16.7	......	......	......	......	......	......	......	......	....
Unnamed	2949	.4	......	......	......	......	......	......	......	......	....
Do	4377	......	......	......	......	......	8.6	22.0	......	15.3	....

[a] Yield computed from 0.004 acre.

[b] Actual yield from 0.004 acre.

In the Fife group, Ghirka Spring is the only variety that has been grown during the entire eight years. It has given a lower yield than the durums, and Table XIV shows that the weight per bushel is about 2 pounds less. The Bluestem group has not been tested extensively, but the yields obtained are not especially promising. The varieties of the Preston group have shown their ability to yield well in dry seasons, but the average for the eight years is low. Table XIV shows that Erivan (C. I. No. 2397) has been ripe an average of four days before any other variety, but the average weight per bushel is only 56 pounds.

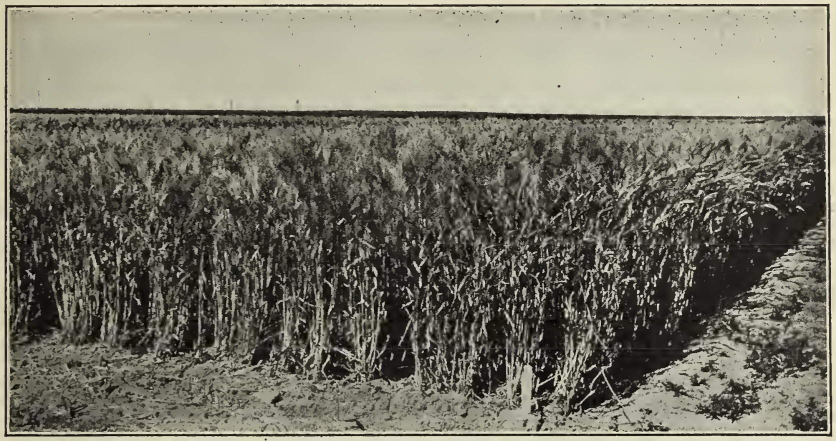

FIG. 5.—Plat of Beloturka durum wheat (C. I. No. 1520) at the Akron Field Station, 1910.

TABLE XIV.—*Average agronomic data, yields per acre, and weights per bushel for eight varieties of spring wheat grown at the Akron Field Station, Akron, Colo., during the 8-year period, 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Average date—		To maturity from—		Height.	Yield per acre.	Weight per bushel.
		Headed.	Ripe.	Planting.	Heading.			
DURUM WHEATS.								
Kubanka:				*Days.*	*Days.*	*Inches.*	*Bush.*	*Pounds.*
Arnautka	1493	June 30	July 30	110	30	36	21.1	61.6
Do[1]	4064	June 29	...do....	109	31	38	24.5	60.9
Beloturka	1520	June 28	July 27	109	27	37	19.5	61.1
Kubanka	1440	June 30	July 28	110	28	33	17.6	61.0
Pelissier:								
Pelissier	1584	June 29	July 31	111	31	35	22.4	60.2
COMMON WHEATS.								
Fife:								
Ghirka	1517	July 2	July 29	108	27	30	18.6	58.7
Preston:								
Erivan	2397	June 30	July 25	102	25	27	18.0	56.0
Miscellaneous:								
Galgalos	2398	June 29	July 29	109	30	24	20.3	57.4

[1] Yields of Arnautka (C. I. No. 1494) used for 1908 and 1909.

Table XIV shows the average dates when the varieties were fully headed and ripe, the length of time from sowing to maturity and from heading to maturity, the average height at maturity, the yield per acre, and the weight per bushel.

The data in Table XIV show that three varieties of durum wheat have averaged at least 61 pounds per bushel. None of the common wheats has averaged more than 57.8 pounds per bushel. The durum varieties have longer straw, which is valuable on account of the difficulty in harvesting grain with short straw. The weather conditions usually force a rapid maturity of all varieties. The result is that the time from sowing to maturity is very uniform. It may be noted that Arnautka, which matures two days later than Kubanka, is recorded as requiring the same number of days from sowing to maturity. The explanation is that the date of sowing was not the same.

NURSERY EXPERIMENTS.

About fifty varieties and several hundred selections of spring wheat have been grown in nursery rows. The object has been to test varieties of unknown value and selections or strains in short nursery rows before giving them space in field plats. If they did not show promise, they were discarded. Some promising selections have been increased for testing in field plats. One of the best of these is Arnautka 6P1, which has been referred to in the discussion of field-plat experiments. Several selections which yielded well in nursery rows failed to outyield the mother variety when grown in field plats and so have been discarded.

RATE-OF-SEEDING EXPERIMENTS.

Rate-of-seeding tests, including four different rates, have been conducted at Akron for five years with durum wheat. Table XV gives the yield data obtained, which show a great lack of consistency. It will be noted that the general trend of increase in 1911 and 1913 was from the lower to the higher rates. These were dry years, when agricultural experience would have favored the reverse order. In 1912, with more abundant moisture, there is a decrease from 41 bushels for the low rate to 27 bushels for the high rate. This, again, is contrary to common belief. In 1914, with a fair rainfall, the order is normal, as gauged by common opinion. In 1915 the yields from the 2-peck rate and from the 6-peck rate are practically the same, and there is very little difference in the yields from all rates. The greatest departure was 0.7 bushel per acre. Under these conditions the average for the five years can not carry much weight. The average for the 2-peck rate is 21.2 bushels, and that for the 5-peck rate is the same. The data seem to indicate that within certain limits the rate does not materially affect the yield.

TABLE XV.—*Annual and average yields of durum wheat in a rate-of-seeding test at the Akron Field Station, Akron, Colo., 1911 to 1915, inclusive.*

Rate of seeding (per acre).	Yield per acre (bushels).						
	1911	1912	1913	1914	1915	Average.	
						1911 to 1915.	1912 to 1915.
2 pecks	9.9	41.0	7.3	18.0	30.0	21.2	24.1
3 pecks	9.8	37.3	8.6	19.6	29.5	21.0	23.7
4 pecks	10.8	37.0	11.0	20.0	29.5	21.7	24.4
5 pecks	12.6	30.3	11.6	22.0	29.5	21.2	23.3
6 pecks	....	28.3	11.2	21.3	30.2	....	22.7
7 pecks	....	27.0	11.6	21.0	....	....	....

COMPARISON OF WINTER AND SPRING WHEAT.

It is of importance to know whether winter or spring wheat will give the best returns. Table XVI shows the annual and average yields of nine varieties of winter and spring wheat grown on the Akron Field Station during the eight years, 1908 to 1915, inclusive. Figure 6 shows the average yields in graphic form.

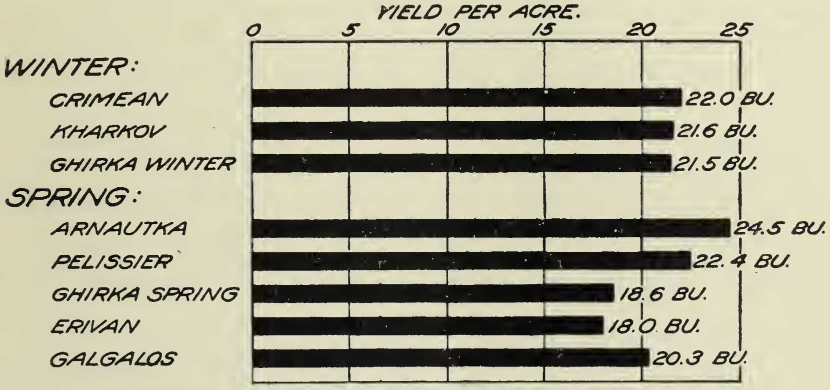

FIG. 6.—Diagram showing the average yields of the leading varieties of wheat at the Akron Field Station, 1908 to 1915, inclusive.

TABLE XVI.—*Annual and average yields of nine varieties of wheat grown at the Akron Field Station, Akron, Colo., during the 8-year period, 1908 to 1915, inclusive.*

Variety.	C. I. No.	Yield per acre (bushels).								
		1908	1909	1910	1911	1912	1913	1914	1915	8-year average.
Winter varieties:										
Crimean	1436	19.1	0	38.3	17.9	33.1	12.6	28.3	26.6	22.0
Kharkof	1583	19.3	0	29.8	14.2	37.5	16.6	25.9	29.2	21.6
Ghirka Winter	1438	15.6	0	38.5	15.8	38.3	17.3	24.0	22.8	21.5
Spring varieties:										
Arnautka	1494 4064	18.7	11.8	19.5	15.7	37.3	10.6	25.0	27.6	24.5
Pelissier	1584	24.7	23.6	15.8	10.6	35.6	10.5	26.6	31.6	22.4
Arnautka	1493	26.9	20.8	16.6	10.6	27.5	10.5	27.6	27.6	21.1
Galgalos	2398	21.8	19.8	20.5	19.6	20.5	14.1	21.7	24.4	20.3
Ghirka Spring	1517	20.6	23.8	18.8	8.5	23.3	11.6	19.3	22.6	18.6
Erivan	2397	19.3	26.3	15.2	11.9	20.7	12.0	19.3	19.5	18.0

The yields of two varieties of durum wheat have averaged slightly higher than those of the best winter variety. However, in the case of the winter variety there was one year of failure, which may not occur again in a long series of years. If this is true, the winter wheat will probably take first rank. It should also be noted that when winter wheat winterkills, the land can be resown to spring wheat. The winter wheat should then be credited with the returns from the spring wheat grown on the land that year, less the cost of seed and sowing. If this were done for the year of failure in Table XVI it would place winter-wheat yields above those of spring wheat. At present there is probably greater value represented in the slightly lower yield of winter wheat on account of the higher market price. In case the grain is ground and used for feed the market price would not be a factor.

In 1908 the durum wheats produced about 25 per cent more grain than the winter wheats, while the common spring wheats gave yields about equal to the winter varieties. In 1909 the spring wheats yielded well and winter wheats failed. In 1910 winter wheats produced nearly double the yields of spring wheat. In 1911 the winter-wheat yields were about 50 per cent higher than those of any of the spring varieties except Galgalos, which yielded 1.7 bushels per acre more than the best winter variety. In 1912 the winter-wheat yields averaged about 40 per cent more than the spring-wheat yields. In 1913, 1914, and 1915 the differences were not great.

To summarize: In 1909 spring wheat gave good yields, while winter wheat was a failure; in 1910, 1911, and 1912 the winter-wheat yields were distinctly larger than those of spring wheat; while in 1908, 1913, 1914, and 1915 the differences were not great. For the eight years, the average yields of the winter varieties and durum spring varieties are about equal, while the spring commons are 2 to 3 bushels lower. When all the facts are considered, it appears that winter wheat will return more value per acre than spring wheat.

EXPERIMENTS WITH OATS.

The better varieties of oats have made fair yields at the Akron Field Station in all except one of the eight years during which they have been tested. In 1911 the yields were low except that of Colorado No. 37 (C. I. No. 619), which was located on a plat that received some extra water from run-off. Four varieties have been grown during the entire eight years. The average yield of these four varieties was 42.5 bushels per acre. They include two early and two midseason varieties. The average yield of the midseason group is slightly larger than that of the early group.

VARIETAL EXPERIMENTS.

Varietal experiments with oats have been conducted both in field plats and in the nursery.

PLAT EXPERIMENTS.

Fifteen varieties and several strains of spring oats have been grown in field plats. One of the strains shows some promise and is reported in this bulletin. Others have failed to produce yields superior to those of the parent varieties and have been discarded. No variety of the late groups has been grown continuously. Table XVII shows the annual and average yields of the 16 varieties and strains grown on the Akron Field Station in the 8-year period from 1908 to 1915, inclusive. They have been divided into three groups, according to the time of maturity.

Table XVII.—*Annual and average yields of 16 varieties and strains of oats grown at the Akron Field Station, Akron, Colo., 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).									
		1908	1909	1910	1911	1912	1913	1914	1915	Average.	
										Eight years.	All years grown.
Early:											
Burt	293	......	......	......	......	48.2	36.8	63.1	82.6	....	57.4
Kherson	459	52.8	33.1	37.1	12.4	36.0	36.1	65.0	85.0	44.7	44.7
Perm	170	......	......	......	2.0	34.5	20.6	50.5	78.0	....	37.1
Sixty-Day	165	42.9	37.2	21.9	3.3	33.4	28.1	65.0	82.6	39.3	39.3
Sixty-Day, 4P2	788	......	......	32.0	4.2	40.0	26.2	61.2	74.2	....	39.6
Midseason:											
Canadian	444	19.2	53.1	29.4	......	......	......	......	......	....	25.4
Colorado No. 37	619	36.8	55.6	29.9	32.5	30.9	32.5	53.7	79.2	43.9	43.9
Danish	441	40.8	......	......	......	......	......	......	......	....	....
Early Champion	......	41.8	25.0	34.8	......	......	......	......	......	....	33.9
Lincoln	738	......	......	......	......	......	41.2	61.2	67.8	....	56.9
Red Rustproof	451	......	......	20.8	......	......	......	......	......	....	....
Silvermine	659	......	......	......	......	......	38.1	42.5	......	....	40.3
Swedish Select	134	62.5	50.6	29.5	15.9	30.9	27.5	48.7	69.4	41.9	41.9
Late:											
White Tartarian	300	19.7	......	......	......	23.4	23.7	42.1	65.0	....	34.8
White Russian	551	18.8	......	......	......	......	......	......	......	....	....
Yellow Giant	342	19.2	......	......	......	......	......	......	......	....	....

As shown in Table XVII, the Kherson (C. I. No. 459) has an average yield of 44.7 bushels per acre for the 8-year period. The variety ranking second is Colorado No. 37 (C. I. No. 619) in the midseason group. Its average yield is 43.9 bushels. When deduction is made for the favorable location of Colorado No. 37 in 1911, the average yield becomes the same as that of Swedish Select (C. I. No. 134), 41.9 bushels. The Sixty-Day variety (C. I. No. 165) has yielded less than the Kherson variety in all years except 1909. Its average yield of 39.3 bushels per acre is 5.4 bushels less than that of the Kherson. The selection of the Sixty-Day variety, listed as Sixty-Day 4P2, seems to be just about equal to the parent variety. A plat of a pure-line selection of Sixty-Day oats is shown in figure 7. The Burt oat (C. I. No. 293) has been grown only four years. In these years it has averaged 57.9 bushels, as compared with 55.5 bushels from the Kherson variety for the same period.

In the fall of 1907 a plat of Boswell Winter oats was sown. While the winter survival was low, the plat yielded at the rate of 15.7 bushels per acre. Seed of this variety has been sown five other years, and each time the plants have entirely winterkilled.

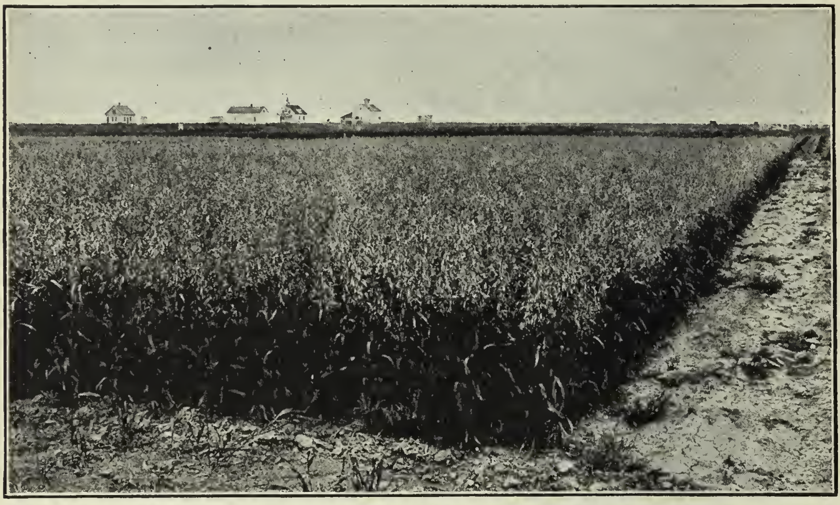

FIG. 7.—Plat of a pure-line selection of Sixty-Day oats at the Akron Field Station, with the farm buildings in the background, in 1910.

Table XVIII shows the average dates of heading and maturity, height, weight per bushel, and yield of five varieties of oats representing all three of the spring groups. The White Tartarian was not grown in 1909, 1910, and 1911. The average yields are shown graphically in figure 8.

TABLE XVIII.—*Average dates of heading and maturity, height, yield of grain and straw, and weight per bushel of five varieties of oats grown at the Akron Field Station, Akron, Colo., 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Dates of—		Height.	Yield per acre.		Weight per bushel.
		Heading.	Maturity.		Grain.	Straw.	
				Inches.	*Bushels.*	*Pounds.*	*Pounds.*
Early:							
Kherson	459	June 26	July 20	27	44.7	1,394	31.3
Sixty-Day	165	June 27	July 19	27	39.3	1,418	30.6
Midseason:							
Colorado No. 37	619	July 6	Aug. 1	31	43.9	2,014	35.0
Swedish Select	134	July 8	July 31	32	41.9	2,119	32.5
Late:							
White Tartarian[1]	300	July 11	Aug. 9	34	34.8	2,538	34.0

[1] Not grown in 1909, 1910, and 1911.

The data in Table XVIII show that the difference in date of maturity between the early and midseason and between the midseason and late groups is about 10 days. The varieties in the early group mature about July 20, those of the midseason group about July 31, and those of the late group about August 9. There is an increase of about 500 pounds per acre in the straw yield of each successively later group. As oat straw has considerable feeding value this should be taken into account. Considering yields of both grain and straw, the midseason variety, Colorado No. 37 (C. I. No. 619), has given the best returns during the period.

NURSERY EXPERIMENTS.

A total of 61 varieties and several hundred strains have been tested in nursery rows. The varieties that have shown promise have been advanced to the field tests. With the exception of Sixty-Day 4P2, they have not proved worthy of continued trial and have been discarded. The nursery tests have served to eliminate a large quantity of material not adapted to the conditions at Akron. The results are of a negative rather than a positive nature.

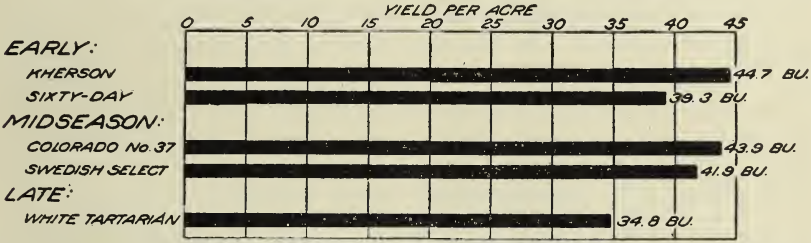

FIG. 8.—Diagram showing the average yields of the leading varieties of oats at the Akron Field Station, 1908 to 1915, inclusive.

RATE-OF-SEEDING EXPERIMENTS.

An experiment was begun in 1911 to investigate the effect of rate of seeding on the yield per acre of oats. The Kherson variety (C. I. No. 459) has been used. Table XIX shows the annual and average yields obtained during the five years.

TABLE XIX.—*Annual and average yields of Kherson oats in a rate-of-seeding test at the Akron Field Station, Akron, Colo., 1911 to 1915, inclusive.*

Rate of seeding per acre.	Yield per acre (bushels).						
	1911	1912	1913	1914	1915	Average.	
						1911 to 1915	1912 to 1915
2 pecks	6.9	46.9	30.0	74.4	85.0	52.1	59.1
3 pecks	10.6	61.7	23.1	71.8	86.9	50.8	60.9
4 pecks	13.1	40.0	40.6	84.4	87.5	53.1	63.1
5 pecks	13.8	43.1	25.0	65.0	90.0	47.4	55.7
6 pecks	....	71.9	18.2	73.8	90.6	....	63.6

What has been true of other similar tests at the Akron Field Station is true of the rate-of-seeding test with oats, namely, that the data are not consistent. In 1911, which was a dry year, there was a gradual increase in yield as the rate of seeding increased. In 1912 there was no uniform variation. The 6-peck rate yielded 71.9 bushels per acre, the 4-peck rate 40 bushels, and the 3-peck rate 61.7 bushels. In 1913 the data show an exact reverse. The 6-peck rate produced the lowest yield, the 4-peck rate the highest yield, and the 3-peck rate next to the lowest. In 1914, again, the highest yield came from the 4-peck rate, but the 3-peck and 5-peck rates are both lower in yield than the 2-peck and the 6-peck rates. In 1915 there is a return to a uniformly gradual increase in yield as the rate increases from 2 pecks to 6 pecks.

It seems probable that a part of the lack of uniformity throughout the experiment may be due to soil variation. The 4-peck rate has produced the highest average yield in the five years. The 4-year average from the 6-peck rate is highest, but two seasons of favorable rainfall are included. In the one year of low rainfall, 1913, the 6-peck rate produced less than half the yield from the 4-peck rate. The conclusion drawn from the data available at the present time is that the 4-peck rate will produce the highest yield under average conditions.

EXPERIMENTS WITH BARLEY.

In this section of the Great Plains spring barley is grown both for farm use as a feed and for market. One variety may be best adapted for feeding and another prove to be best to grow for market. Several varieties and strains of barley have been tested, and four of these, representing three groups, have been grown for eight years. The 8-year average yield of four hulled barleys is 35.9 bushels per acre. No rate-of-seeding tests have been conducted with barley.

Varietal tests of barley have been conducted on field plats and in the nursery.

PLAT EXPERIMENTS.

The varietal tests of barley have become more extensive from year to year. Table XX shows the annual and average yields of 19 varieties of barley grown at the Akron Field Station for varying periods from 1908 to 1915, inclusive.

The 2-rowed hulled group contains the Blackhull (C. I. No. 878), which has black glumes, and nine other varieties with light glumes. All of this group have beards. The 6-rowed hulled group contains Arlington Awnless (C. I. No. 702), which has light glumes and no beards; Coast (C. I. No. 690), with white glumes and long heavy beards; Horsford (C. I. No. 877), light glumes and hooded; and Gatami (C. I. No. 575), with black glumes and beards. The data show that of the varieties grown throughout the 8-year period, Hannchen (C. I. No. 602) has produced the highest average yield per acre. Its average of 38.7 bushels is 0.7 bushel higher than that of Coast, C. I. No. 690 (formerly grown and distributed as California Feed). Hanna (C. I. No. 226) ranks third, with an average yield of 34.3 bushels. White Smyrna (C. I. No. 658) is the only variety recently introduced into the tests which shows promise of outyielding those already mentioned.

Table XX.—*Annual and average yields of 19 varieties of barley grown in field plats at the Akron Field Station, Akron, Colo., during the eight years from 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).									
		1908	1909	1910	1911	1912	1913	1914	1915	Average.	
										All years grown.	8-year period.
SPRING VARIETIES.											
2-rowed hulled:											
Blackhull	878	25.4	20.1	23.8	5.8	26.6	25.4	42.9	77.1	30.9	30.9
Hanna	24	......	......	23.5	12.9	43.1	18.3	40.7	72.2	35.1	....
Do	203	......	......	29.2	13.1	42.1	27.2	42.5	......	30.8	....
Do	226	34.2	22.2	26.6	15.4	34.2	29.1	42.5	70.5	34.3	34.3
Hannchen	531	......	......	......	......	56.7	22.5	45.9	......	41.7	....
Do	602	47.8	20.7	28.2	10.4	34.7	22.1	59.6	86.0	38.7	38.7
Mansury	617	31.2	12.1	......	......	......	......	......	......	21.7	....
Orel	351	......	......	......	......	......	32.0	42.5	73.3	49.3	....
Primus	532	......	......	32.3	2.3	17.9	6.6	42.1	......	20.2	....
White Smyrna	658	......	......	......	27.5	35.8	20.4	70.4	80.9	47.0	....
2-rowed naked:											
Baku[1]	709	......	......	......	......	28.6	5.4	......	......	17.0	....
6-rowed hulled:											
Arlington Awnless	702	......	......	......	......	......	22.9	41.6	......	32.2	....
Coast (California Feed)	690	38.6	32.8	25.5	16.7	38.5	22.5	50.5	79.1	38.0	38.0
Horsford	877	31.9	22.3	21.2	7.9	30.0	16.5	24.0	......	25.6	....
Gatami	575	......	......	......	......	......	25.4	65.0	......	45.2	....
Manchuria	643	......	21.5	18.4	15.2	34.6	25.4	40.0	......	25.9	....
6-rowed naked:											
Nepal[1]	595	31.5	26.3	19.4	0.6	18.8	6.8	41.6	56.0	25.1	25.1
Mixture:											
Composite	1147	......	......	......	......	......	21.6	44.5	66.0	44.0	....
WINTER VARIETY.											
6-rowed hulled:											
Tennessee Winter	257	......	......	5.8	9.4	15.4	19.1	......	......	8.3	....

[1] Yields computed at 48 pounds per bushel; actual weight about 56 pounds.

The variety commonly called "Bald" or "White Hull-less" barley is here called Nepal, its proper name. Although naked barley has about the same bushel weight as wheat, it is here computed at 48 pounds, in order that the naked varieties may be more easily compared with the hulled ones. On this basis the yield of the Nepal variety is 25.1 bushels. Pound for pound it is more valuable than hulled barley, as the latter contains from 10 to 12 per cent of hulls. Deducting for these, the 25.1 bushels of Nepal barley is nearly equal to 28.7 bushels of hulled barley.

Winter barley has winterkilled to such an extent that the average yield is low. In two years out of six the winter barley has failed. The average yield for the six years is 8.3 bushels to the acre.

The average dates of heading and maturity, height, yield of grain and straw, and weight per bushel of five varieties of barley which were grown at the Akron Field Station during the 8-year period from 1908 to 1915, inclusive, are given in Table XXI. The average yields are shown graphically in figure 9. Blackhull (C. I. No. 878) has averaged five days earlier in maturing than Coast (C. I. No. 690). The ripening date of Blackhull is July 15, and that of Coast July 20. Hannchen (C. I. No. 602) and Hanna (C. I. No. 226) are still later, averaging July 22 and July 24, respectively.

The quality of grain, as shown by weight per bushel, puts Hannchen in the lead and Hanna a close second. Although the Coast barley has a plump, heavy grain, it does not thrash clean. The fragments of awns prevent its packing and the tester shows it to weigh only 39 pounds per bushel, or 9 pounds below the standard weight. The straw weights do not vary sufficiently to need comment.

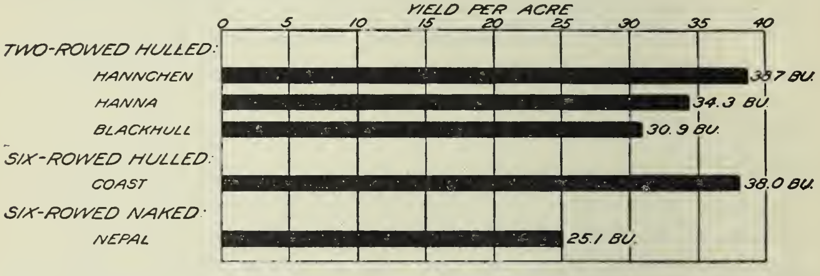

Fig. 9.—Diagram showing the average yields of the leading varieties of barley at the Akron Field Station, 1908 to 1915, inclusive.

Table XXI.—*Average dates of heading and maturity, height, yield of grain and straw, and weight per bushel of five varieties of barley grown at the Akron Field Station, Akron, Colo., during the 8-year period, 1908 to 1915, inclusive.*

Group and variety.	C. I. No.	Dates of—		Height.	Yield per acre.		Weight per bushel.
		Heading.	Maturity.		Grain.	Straw.	
				Inches.	*Bushels.*	*Pounds.*	*Pounds.*
2-rowed hulled:							
Blackhull	878	June 18	July 15	28	30.9	1,696	46.5
Hanna	226	July 2	July 24	28	34.3	2,291	47.0
Hannchen	602	June 30	July 22	26	38.7	1,973	47.5
6-rowed hulled:							
Coast (California Feed)	690	June 25	July 20	28	38.0	2,134	39.0
6-rowed naked:							
Nepal (White Hull-less)	595	June 28	July 22	26	[a] 25.1	1,771	57.8

[a] For comparison, computed at 48 pounds per bushel.

NURSERY EXPERIMENTS.

The nursery tests with barley have included 75 varieties and numerous strains. The object has been to discover valuable new material, and when a variety or selection did not prove itself superior to varieties already in field plats it was discarded. The few that have been worthy of field tests are included in Table XX. Figure 10 shows a view of the barley nursery in 1912.

EXPERIMENTS WITH MINOR CEREALS.

RYE.

Winter rye has been grown in field plats for two years on the Akron Field Station. The average yield in the two years was 26.1 bushels per acre. This is much below the wheat yields in the same years. The blooming of the flowers at a time when dry, hot winds are common causes a partial sterility of the heads and a resultant reduction in yield. At present rye is not grown as a grain crop, but as a catch crop for forage.

EMMER.

Winter emmer has been sown each of the eight years, 1908 to 1915, inclusive. The crops of 1909 and 1915 were failures. The highest yield, 29.5 bushels, was produced in 1908. The 8-year average yield of Black Winter emmer (C. I. No. 2337) is 14.2 bushels per acre. Good stands are usually obtained, but a high percentage of winterkilling occurs, and low yields result. Winter emmer can not be recommended for this district.

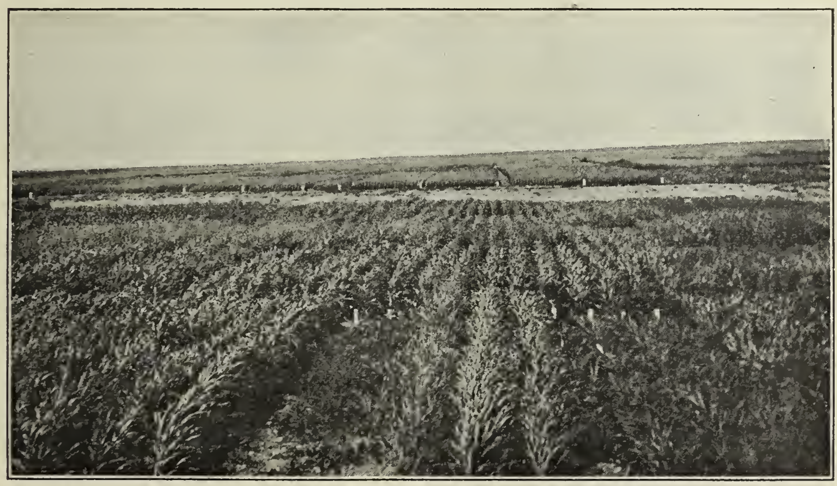

FIG. 10.—Barley nursery at the Akron Field Station in 1912.

White Spring emmer (C. I. No. 1524) has given fair yields in each of the eight years it has been grown. The lowest yield, 11.1 bushels, was produced in 1910, and the highest yield, 69 bushels, in 1915. The average acre yield has been 30.3 bushels. Spring emmer is therefore a fair producer, but it has not been a close competitor of either wheat or barley.

FLAX.

Flax has been sown in each of the eight years during which experiments have been conducted at Akron. In the three years, 1911, 1914, and 1915, the crop failed. Russian (C. I. No. 19) has been grown throughout the 8-year test. The highest yield recorded was 13.1 bushels per acre, produced in 1912. Other varieties have been grown for shorter periods, but none has proved superior to the Russian. The 8-year average yield of this variety is 4.4 bushels per acre.

PROSO.

Proso, commonly called hog millet or broom-corn millet, has not been given a very thorough test. It has been grown in nursery rows and small plats, but continuous field-plat tests have not been made. Black Voronezh (C. I. No. 16) or selections from it has been grown during five years. A plat of this variety in 1915 is shown in figure 11. It was first sown in field plats in 1909, when it produced a yield of 22.9 bushels per acre. It was again sown in field plats in 1912 and each of the three years following. The highest yield recorded was 36 bushels in 1912. The 5-year average is 23.1 bushels. Except possibly as a catch crop, proso can not be recommended for this district.

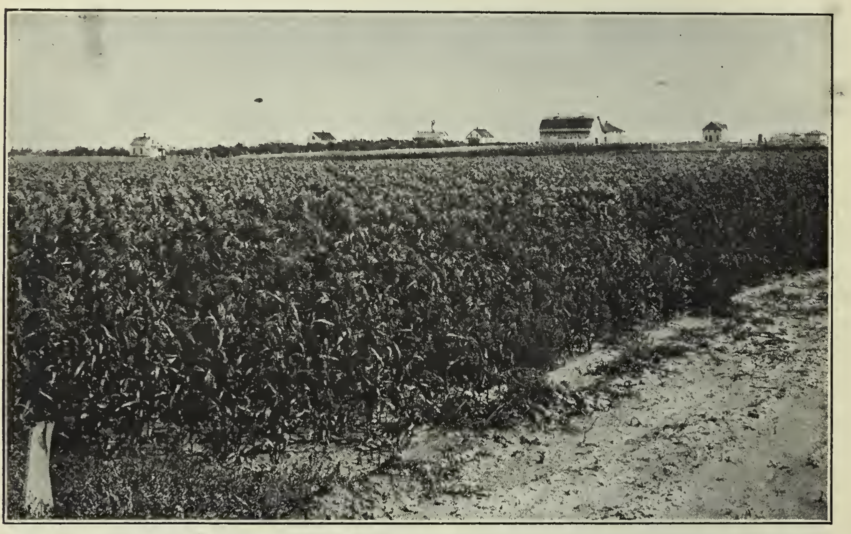

FIG. 11.—Plat of Black Voronezh proso at the Akron Field Station, with the station buildings in the background, in 1915. (From a photograph lent by the Office of Exhibits, U. S. Department of Agriculture.)

GRAIN SORGHUMS.

Grain sorghums have been grown in field plats for five years. On account of the short growing season and cool nights, most varieties fail to mature. Manchu Brown kaoliang (C. I. No. 328) is the only variety of apparent value in the Akron district. The highest yield was 18.7 bushels, produced in 1913. The lowest yield, 11.7 bushels, was produced in 1915. The average yield in the five years, 1911 to 1915, inclusive, was 15.4 bushels. Because of the fact that some of the sorgos, or saccharine sorghums, produce as much grain and in addition yield more forage, grain sorghums can not be recommended to farmers of this district at the present time. Farther south and east, milo and dwarf milo are well adapted.

SUMMARY.

Cooperative experiments with cereals have been conducted at the Akron Field Station during the eight years, 1908 to 1915, inclusive.

The station is located in the north-central part of Washington County, in northeastern Colorado, at an altitude of approximately 4,560 feet.

The average annual precipitation in the 11 years, 1905 to 1915, inclusive, was 19.72 inches. The average seasonal rainfall (March to July, inclusive) was 12.33 inches. About two-thirds of the rainfall occurs during the growing season.

The average evaporation from a free water surface during the six months from April to September, inclusive, for the 8-year period, 1908 to 1915, inclusive, was 42.08 inches. The average precipitation in the same period was 14.11 inches.

The average hourly wind velocity during the months from April to September, inclusive, for the eight years was 7.1 miles.

The average length of the frost-free period for the eight years was 136 days. The average date of the last killing frost in spring was May 13, and of the first killing frost in autumn, September 26.

The soil of the Akron Field Station is a fine sandy loam.

The cereals tested on field plats have included 17 varieties and strains of winter wheat, 44 of spring wheat, 16 of oats, 19 of barley, and one or more of each of the minor cereals, rye, emmer, flax, proso, and grain sorghums.

Winter wheat has given better results than spring wheat. The durum wheats have produced higher average yields than spring common wheats.

Crimean winter wheat (C. I. No. 1436) produced the highest average yield of any winter wheat tested during the eight years, 1908 to 1915, inclusive, namely, 22 bushels. The Kharkof variety (C. I. No. 1583) ranks second, with 21.6 bushels.

Pelissier durum wheat (C. I. No. 1584) produced 22.4 bushels, the highest average yield of any spring wheat in the eight years, 1908 to 1915, inclusive. The Velvet Don (C. I. No. 1445) was second, with a yield of 21.5 bushels, and the Arnautka (C. I. No. 1493) third, with

21.1 bushels. Ghirka Spring wheat, of the Fife group, yielded 18.6 bushels.

Rate-of-seeding tests with winter wheat have not been satisfactory, but 3 pecks is thought to be the best rate.

Date-of-seeding tests with winter wheat indicate that the period between September 15 and October 15 is the best time to sow.

A rate-of-seeding test with spring wheat indicates that sowing 3 to 4 pecks will produce the best yields.

Considering yields per acre and market value, winter wheat is more profitable than spring wheat and spring durum more profitable than spring common wheat.

The best varieties of oats tested in the eight years, 1908 to 1915, are Kherson, with an average yield of 44.7 bushels, and Colorado No. 37, yielding 43.9 bushels. The Kherson is an early variety and Colorado No. 37 a midseason variety. Late varieties have yielded much less than the early or midseason varieties.

Rate-of-seeding tests with the Kherson oats indicate that the best yields are obtained by sowing 4 pecks per acre.

The best varieties of barley tested in the eight years are the Hannchen (C. I. No. 602), with an average yield of 38.7 bushels, and the Coast (C. I. No. 690), with a yield of 38.0 bushels. The 2-rowed group of barleys has averaged better than the 6-rowed group.

Winter rye has proven inferior in value to wheat.

Winter emmer has not been able to withstand winterkilling sufficiently. The 8-year average yield is 14.2 bushels.

White Spring emmer has averaged 30.3 bushels per acre and is therefore inferior to wheat or barley.

Flax has not produced well on account of its inability to successfully compete with weeds.

Proso, grown in field plats for five years, has averaged 23.1 bushels. Its main value seems to be as a catch crop.

No grain sorghum has made good yields. Most varieties fail to mature. The 5-year average yield of Manchu Brown kaoliang is 15.4 bushels per acre.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE TREATING OF CEREAL PRODUCTION IN THE GREAT PLAINS.

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Cereal Experiments at Dickinson, N. Dak. Department Bulletin 33.

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Oats in the Great Plains Area: Relation of Cultural Methods to Production. Department Bulletin 218.

Barley in the Great Plains Area: Relation of Cultural Methods to Production. Department Bulletin 222.

The Effect of Different Times of Plowing Small-Grain Stubble in Eastern Colorado. Department Bulletin 253.

Crop Production in the Great Plains Area: Relation of Cultural Methods to Yields. Department Bulletin 268.

Cereal Experiments at the Williston Substation. Department Bulletin 270.

Cereal Investigations on the Belle Fourche Experiment Farm. Department Bulletin 297.

Alaska and Stoner, or "Miracle," Wheats: Two Varieties Much Misrepresented. Department Bulletin 357.

Sixty-Day and Kherson Oats. Farmers' Bulletin 395.

Oats: Distribution and Uses. Farmers' Bulletin 420.

Oats: Growing the Crop. Farmers' Bulletin 424.

Barley: Growing the Crop. Farmers' Bulletin 443.

The Smuts of Wheat, Oats, Barley, and Corn. Farmers' Bulletin 507.

Durum Wheat. Farmers' Bulletin 534.

Growing Hard Spring Wheat. Farmers' Bulletin 678.

Varieties of Hard Spring Wheat. Farmers' Bulletin 680.

Marquis Wheat. Farmers' Bulletin 732.

Cereal Crops in the Panhandle of Texas. Farmers' Bulletin 738.

Grains for Montana Dry Lands. Farmers' Bulletin 749.

Winter Wheat in Western South Dakota. Bureau of Plant Industry Circular 79.

Hard Wheats Winning Their Way. Separate 649, Yearbook (1914), 1915.

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Experiments with Wheat, Oats, and Barley in South Dakota. Department Bulletin 39. Price, 10 cents.

The Commercial Status of Durum Wheat. Bureau of Plant Industry Bulletin 70. Price, 10 cents.

Improving the Quality of Wheat. Bureau of Plant Industry Bulletin 78. Price, 10 cents.

The Loose Smuts of Barley and Wheat. Bureau of Plant Industry Bulletin 152. Price, 15 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 403

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C. September 21, 1916

A SYSTEM OF ACCOUNTS FOR LIVE-STOCK SHIPPING ASSOCIATIONS.

By John R. Humphrey and W. H. Kerr, *Investigators in Market Business Practice.*

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INTRODUCTION.

The increase in the volume of business of individual cooperative live-stock shipping associations, as well as the growth in number of such associations, has made it generally practicable and in some cases urgent that a simple method of accounting be made available for their use.

The simplicity in operation of associations organized for the exclusive purpose of shipping live stock cooperatively has tended toward producing lax methods of accounting which give no general idea of the financial condition of the associations. It is possible in some instances to make a complete and final settlement to members after returns have been made by the commission merchant for each shipment; nevertheless it is important that these transactions be kept in an orderly way if for no other reasons than for the detection of errors and the furnishing of a permanent consecutive record of the business.

Note.—This bulletin is of interest to live-stock shipping associations and persons contemplating the organization of such associations.

50915°—Bull. 403—16

While agricultural marketing organizations are founded primarily for the disposal of products of the farm to the central market, in a majority of cases they have found it necessary for the convenience of their patrons to handle certain lines of farm supplies. Many live-stock shipping associations are at present selling grains and prepared feeds to the farmers, and as this is done to some extent on credit accurate accounts receivable must be kept.

The system of accounts devised by the Office of Markets and Rural Organization and described in this bulletin has been so constructed as to meet the requirements of shipping associations under varying conditions at a minimum expenditure of time and bookkeeping effort,[1] and is the result of investigations made by the office in cooperation with several live-stock shipping associations in various States where the system is now in successful operation. Special care has been taken to make the method of application as direct as possible and to cut to a minimum the number of forms necessary to do the work properly. It is well understood that not all the forms included in the system will be needed under every condition of operation, but such forms as are suggested will be found practicable for use in every association attempting to keep an accurate account of the transaction of its business.

TYPES OF SHIPPING AGENCIES.

The efforts of farmers to market their own live stock where sufficient animals are available to support united efforts usually have resulted in the formation of a corporation or association equipped with the necessary establishment to do the work. This often includes a yard and scale and the employment of a buyer or manager, with provision for an office at or near the yard. Where such associations have been formed and have not had sufficient business to make it profitable to keep a manager, individual farmers have taken turns at shipping for the association. This method can not be recommended, however, as some one should have a continuous knowledge of the affairs of the association to insure proper service.

Individual buyers having an established business at a certain point frequently make it a practice to ship for farmers on commission on the same basis used in shipping associations. This arrangement is common only in places where but few farmers have the desire to sell at terminal market prices. In any case, the accounting records necessary would be similar.

---

[1] For a further discussion of general subjects relating to live-stock shipping associations, see Doty, S. W., and Hall, L. D., "Cooperative Live-Stock Shipping Associations," U. S. Department of Agriculture, Farmers' Bul. 718, 1916.

FINANCING SHIPPING ASSOCIATIONS.

In order that a live-stock shipping association may conduct its business along safe lines it is advisable that the organization be incorporated. If organized under a law requiring capital stock, shares in the corporation may be sold at a price sufficient to bring in the necessary capital, but the amount which has been found most successful for the par value of shares has been from $10 to $25. In some associations it has been found feasible after incorporation to sell shares in order to procure capital and to issue memberships at $5 each to all patrons not desiring to buy stock. In course of time many of the holders of memberships who have had a chance to test out the value of the shipping association desire to become stockholders, and it is therefore advisable to make the memberships convertible into stock at their face value.

Under the corporation laws of some States provision is made for the chartering of nonstock cooperative enterprises. Where incorporation is had under one of these laws, provision should be made for a membership fee large enough to bring into the treasury sufficient funds to conduct the business.

A live-stock shipping association in its simplest form would not require incorporation or an extensive capital, but if any considerable amount of business is done it will be found necessary to expend money on equipment, and this will require an outlay of capital before sufficient business can be done to lay aside a fund necessary for these purposes. It is not wise, therefore, to consider the formation of an association without adequate provision for meeting needed expenditures.

ACCOUNT SALES.

The account sales rendered by the commission merchant at the terminal market to the shipping association, an example of which is shown on page 4, furnishes all the original material from which the accounts dealing with live stock are derived. Account sales, when rendered with reference to mixed shipments, should show the number of animals of each kind and grade, together with weight, price, the amount sold for, and marks as applied to each kind and grade. In addition, it should furnish the total of expenses and deductions, which should be supported by an itemized list showing what items are charged for and the amount of each. The difference between the total sale value and the shipping expenses is the net proceeds to the association. From this must be taken the association expenses and deductions, leaving the amount to be distributed to the members represented in the shipment.

[Name of Commission Firm.]

(Market).................... (Date)...........

Sold for account of...

No...... Shipping point.............................. Post office..............................

Purchasers.	Cattle.	Hogs.	Sheep.	Weight.	Dock.	Price.	Amount.		Total.	

Car No.	R. R. weights.	Rate.			Freight charges.....				
					Yardage...........				
					Hay.......... lbs..				
					Corn......... bush..				
					Inspection..........				
					Insurance...........				
					Commission.........				
					Net proceeds........				
					Proceeds remitted to.				

DESCRIPTION OF THE OFFICE OF MARKETS AND RURAL ORGANIZATION LIVE-STOCK SHIPPING SYSTEM.

Certain features in a system of accounting devised for uniform adoption by any particular line of business may be found unnecessary in specific instances. For example, a provision for the sale of supplies included in the cash journal of this system will not be needed by associations which do not handle feed and supplies. The omission of such provisions, however, would make the system unsuitable to the requirements of many other associations, and their inclusion has been found to be of no disadvantage in any case.

In order to include all the necessary features required in live-stock shipping-association accounting, the system devised by the Office of Markets and Rural Organization and described in this bulletin is comprised of the following seven forms:

1. Cash journal.
2. Shipment record envelope.
3. Member's receipt.
3a. Member's account sales.
4. Manifest.
5. Sales ticket.
6. Cash receipt.

THE CASH JOURNAL.

The Cash Journal, Form No. 1, pages 6 and 7, is a multi-column cash book and journal combined, with provision for a detailed account of sales of supplies. This book and an ordinary form of loose-leaf ledger consitute the only books of record required.

SHIPMENT RECORD ENVELOPE.

The shipment record envelope, Form No. 2, page 8, is used for the double purpose of filing the papers relating to a certain shipment so that they will be easily accessible at any time, and of providing a form giving full information concerning the shipment. When an account sales has been received from the terminal market, the data which it contains are transferred to the form on the shipment envelope, where the number of each kind of animals represented in the shipment is set down, together with the home weight, the market weight, and the percentage of shrinkage. The amounts of the different items of expense are then set down opposite their respective items on the shipment envelope in the amount column and the charge per hundredweight on each of these is prorated under the respective kinds of animals in the shipment. An addition of these per hundredweight charges would then give the total per hundredweight charge against each class of animals, which is used as a basis of proration upon the member's account sales. At the bottom of this form are shown the net returns on the shipment and the home expenses and deductions. The difference between these gives the total amount to be remitted to members. A notation at the side shows the date of the remittance and the numbers of statements covered by the remittance.

[Left-hand page.]

CASH JOURNAL.

Office of Markets and Rural Organization, Live Stock System Form No. 1.

Merchandise purchases.		Accounts receivable.	General accounts.	Bank deposits.	Cash.	Folio.	Date.	Items.
Quantity.	Amount.							

Right-hand page.]

CASH JOURNAL.

Office of Markets and Rural Organization, Live Stock System Form No. 1.

Check No.	Folio.	Bank withdrawals.	General accounts.	Accounts receivable.	Sales ticket no.	Merchandise sales.									
						Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.	Lbs.	Amount.

[Shipment record envelope.]

Office of Markets and Rural Organization, Live Stock System Form No. 2.

FARMERS LIVE STOCK SHIPPING ASSOCIATION.

Date.............................. Shipment No......................

Routing.......................... Car initials.........................

Consignee........................ Car No ....

Address......................................

Shipment covered by receipts No..............to No........

Kind.	Number.	Home wt.	Market wt.	Per cent shrinkage.	Remarks.
Hogs............	....	....	....	....	....
Calves..........	....	....	....	....	....
Cattle...........	....	....	....	....	....
Sheep...........	....	....	....	....	....
Total......	....	....	....	....	

Charges.	Amount.	Charge per hundredweight.			
		Hogs.	Calves.	Cattle.	Sheep.
Freight................................	....	....	....	....	....
Yardage and feed....................	....	....	....	....	....
Selling commission...................	....	....	....	....	....
Manager's commission...............	....	....	....	....	....
Incidental expenses..................	....	....	....	....	....
Labor.....................................	....	....	....	....	....
Insurance fund.........................	....	....	....	....	....
....	....	....	....	....	....
Total..................................	....	....	....	....	....

Net returns on shipment..	....	
Home expenses and deductions................................	....	Remittances date.......191
Total remittances..	....	Statements No....to No....

MEMBER'S RECEIPT AND ACCOUNT SALES.

In order that there may be no duplication in the amount of work necessary to secure the original entries with reference to shipments, a form has been provided, whereby a carbon copy of the information contained on the member's receipt, Form No. 3, which is delivered to the farmer at the time of the delivery of his stock, is made upon the member's account sales (see page 9, Form No. 3A), and upon a dupli-

Office of Markets and Rural Organization, Live Stock System Form No. 3.

FARMERS SHIPPING ASSOCIATION.

MEMBER'S RECEIPT.

P. O.............................191

Received from..

No.	Article.	Classification.	Home weight.	Remarks.
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....
....	....	....	....	....

Weigher..

[To be made in duplicate.]

Office of Markets and Rural Organization, Live Stock System Form No. 3a.

Duplicate.]

FARMERS SHIPPING ASSOCIATION.

ACCOUNT SALES.

P. O........................191

In account with..

No.	Article.	Classification.	Home weight.	Shrinkage.	Net weight.	Price.	Amount.
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

Weigher..

Freight.	Selling com.	Incidentals.	Ydg. and feed.	Labor.	Total expense (cwt.).		Total expense (net weight).
....	....	....	....	....	....	Hogs....	....
....	....	....	....	....	....	Veals....	....
....	....	....	....	....	....	Cattle...	....
....	....	....	....	....	....	Sheep...	....

Inclosed find check No.......... for balance due.................... ....

cate of the account sales, which is held in the office. The percentage of shrinkage having been determined on the shipment record envelope, the amount of shrinkage for each member's animals is then obtainable by multiplying the home weight by the percentage of shrinkage. The difference between the shrinkage and the home weight will then give the net weight. This amount multiplied by the price gives the gross receipts for that member's stock. After the individual expense against the shipment has been deducted, the net amount of returns is derived. The member's account sales is then inclosed with a check and mailed to the members. The number of the check is recorded both on the original and duplicate account sales and the duplicate is then filed in the envelope, which contains all the other material regarding the shipment.

MANIFEST.

In order that mistakes and unnecessary delays may be avoided, it is advisable to furnish the commission merchants with a manifest of the shipment (Form No. 4, page 10). The manifest should show the names of the shippers delivering stock to the association, the number of head belonging to each, together with the class and marking. A copy of the manifest should be tacked inside the car, a duplicate sent to the commission firm, and a triplicate kept in the office of the shipping association to be filed in the shipment record envelope.

SALES TICKET AND CASH RECEIPT.

Such associations as deal in supplies will require the use of an ordinary sales ticket covering each sale (Form No. 5, page 11), which should be made out in duplicate, the original being given to the purchaser and the duplicate filed in the office for future reference. When payments are made in cash, the cash receipt (Form No. 6, page 11) should be used, so that the manager may be able to identify such payments.

[To be made in triplicate.]

MANIFEST.

FARMERS SHIPPING ASSOCIATION.

Date, ..., 191..

Shipped to ....

Address..

Car No...................... Routing..

Office of Markets and Rural Organization, Live Stock System Form No. 4.

Name.	No. head.	Kind.	Marking.	Remarks.

SALES TICKET.

FARMERS SHIPPING ASSOCIATION.

Date, ...

Sold to..................................

....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....
....

Total sales..

Office of Markets and Rural Organization—Live Stock System Form No. 5.

CASH RECEIPT.

No......

FARMERS SHIPPING ASSOCIATION.

Received from.............., *Date,* ...., *191*..

For—	Amount.	
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

Office of Markets and Rural Organization—Live Stock System Form No. 6.

ENTERING ACCOUNTS ON THE CASH JOURNAL.

Upon receipt of a check accompanying an account sales from the market, the amount of the check should be entered in the cash column in the cash journal to the debit of cash and credited to live-stock account in the general accounts column. The check covering such a shipment, together with other cash receipts for the period since the last bank deposit (all of which should be entered in the cash column), should then be deposited, and an entry for the amount of the deposit should be transferred to the bank deposits column. Further entries in the cash column will not be added to entries made previous to this deposit, since the cash column serves merely as a memorandum of the amount of receipts, and the various additions from day to day are transferred to the bank deposits column as the deposits are made. After having prorated the returns on the shipment on the members' account sales, the association checks to the members should be entered in consecutive order, giving the name of each patron with the number of the check. The amount of each check is entered in the bank withdrawals column and the total payments charged to the live-stock account in the general accounts column.

Journal entries covering home expenses and deductions relative to the shipment can then be entered. These would include such items as manager's commission and incidental supplies and would be credited to these respective accounts and charged to live stock. The inclusion of these items, together with the checks paid to members, should constitute the total charges to the live-stock account. When a check is issued to the manager for his services, the amount should be charged to the manager's commission account, showing the account balanced for a particular shipment. Such items as stationery, stamps, lumber for partitions, etc., when purchased can be charged to incidental supplies and credited off as used in the manner cited above. The rate charged in the proration of these materials should be such as to credit them off the books at their cost value.

In accounting for sales of supplies, the several columns should be headed according to requirements. All entries of sales may then be distributed under the appropriate headings, showing the pounds and amount of each sale. If the supplies are sold on account, the amount of sales should be charged in the accounts receivable column opposite the customer's name in the items column. The number of the sales ticket should in each case be entered in the sales ticket column. Cash sales should be credited to the proper commodity, as in the case of sales on account, a corresponding amount being entered to the debit of cash in the cash column. As the entries progress and the pages of the cash journal are filled, the various columns should be added and the totals carried forward to the next page. The two sides of the cash journal should at all times be in balance, with the exception that the debit side should exceed the credit by the exact amount of the first entry of the month, which should be the amount of cash in the bank, this entry being made at the head of the bank deposits column. At the close of the last business day of the month the bank book should be balanced, so that the manager will be able to check up the correctness of his entries in respect to cash. If the difference between the totals of the bank deposits column and the bank withdrawals column of the cash journal is equal to the difference between the bank balance as shown in the passbook and the outstanding checks, this will prove that the entries as made in the cash journal correspond to the transactions with the bank, and the two balances therefore are considered reconciled.

POSTING OF THE LEDGER.

In associations which have been doing business over a period of time, it will be necessary before making postings to the ledger to set up the accounts representing the assets and liabilities of the associations.[1] These assets and liabilities will include such assets as cash in the bank, equipment for doing business, notes receivable, accounts receivable, inventory accounts, and such liabilities as bills payable and capital stock outstanding.

Since the cash journal is arranged with columns so that the several commodities may be accounted for in the proper columns, the number of necessary postings to the ledger is reduced. As the work progresses during the month, all the entries in the accounts receivable and general accounts columns, both debit and credit, should be made daily to their respective accounts in the ledger. Such postings as are necessary in respect to various commodities sold can be made at the end of the month in total, posting to the ledger both the amounts in pounds and the values of the commodities sold. In respect to purchases of supplies, the same procedure should be followed regarding posting both pounds and price, so that the ledger account not only will give the value and kind of goods on hand, but will serve also as a perpetual inventory of such commodities.

CONCLUSION.

As has been the practice of the office in relation to its other accounting systems, improvements will be made in the system for live-stock shipping associations described in this bulletin wherever it is shown that such changes will improve its adaptability to the business.

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[1] For further discussion of opening books see Humphrey, John R., and Kerr, W. H., "Lumber Accounting and Opening Books in Primary Grain Elevators," U. S. Department of Agriculture, Markets Document No. 2, 1916.

In connection with its service through the publication of accounting forms and bulletins relating to accounting and business practice in marketing organizations, the office is rendering valuable personal assistance through field representatives. Where deemed advisable and necessary, assistance is furnished to associations in improving their accounting and business methods by assisting in the installation of bookkeeping systems and bv advising the management on improved methods of operation.

The activities of the office are carried on in a spirit of thorough cooperation, and it is hoped that those who accept its services will feel free to become constructive critics of its work.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO SYSTEMS OF FARM ACCOUNTING.

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Farm Bookkeeping (Farmers' Bulletin 511).
A System of Farm Cost Accounting (Farmers' Bulletin 572).
Method of Analyzing the Farm Business (Farmers' Bulletin 661).
Cooperative Live Stock Shipping Association (Farmers' Bulletin 718).
Cooperative Organization Business Methods (Department Bulletin 178).
A System of Accounts for Farmers' Cooperative Elevators (Department Bulletin 236).

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

A System of Accounting for Cooperative Fruit Associations (Department Bulletin 225). Price, 5 cents.

A System of Poultry Accounting (Bureau of Animal Industry Circular 176). Price, 5 cents.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 404

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER October 14, 1916

HEMP HURDS AS PAPER-MAKING MATERIAL.

By Lyster H. Dewey, *Botanist in Charge of Fiber-Plant Investigations*, and Jason L. Merrill, *Paper-Plant Chemist, Paper-Plant Investigations.*

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The production and handling of hemp hurds, by Lyster H. Dewey:

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The manufacture of paper from hemp hurds, by Jason L. Merrill:

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In preparing the report on the manufacture of paper from hemp hurds it became evident that a short discussion of the agricultural aspects of this material should be included in the publication. Such an article was prepared, therefore, and the two reports are here presented together.

THE PRODUCTION AND HANDLING OF HEMP HURDS.

By Lyster H. Dewey, *Botanist in Charge of Fiber-Plant Investigations.*

WHAT HEMP HURDS ARE.

The woody inner portion of the hemp stalk, broken into pieces and separated from the fiber in the processes of breaking and scutching, is called hemp hurds. These hurds correspond to shives in flax, but are much coarser and are usually softer in texture.

Note.—This bulletin should be useful to all persons who are interested in the economic phases of paper making, especially to print and book paper manufacturers. It also should be of interest to scientific investigators and chemists.

The hemp stalk grown in a broadcast crop for fiber production is from one-eighth to three-eighths of an inch in diameter and from 4 to 10 feet tall. The stalk is hollow, with a cylindrical woody shell, thick near the base, where the stalk is nearly solid, and thinner above, where the hollow is relatively wider.

In the process of breaking, the woody cylinder inside of the fiber-bearing bark is broken into pieces one-half of an inch to 3 inches long and usually split into numerous segments. The thicker lower sections are split less than the thin-shelled upper ones, and they are often left quite solid.

PITH, WOOD, AND FIBER.

The inner surface of the hurds usually bears a layer of pith, consisting of thin-walled cells nearly spherical or angular, but not elongated. They are more or less crushed and torn. They are probably of little value for paper, but they constitute less than 1 per cent of the weight of the hurds. The principal weight and bulk consist of slender elongated woody cells. The outer surface is covered with fine secondary fibers composed of slender elongated cells, tougher than those of the wood but finer and shorter than those of the hemp fiber of commerce. No method has been devised thus far which completely separates from the hurds all of the long fiber. From 5 to 15 per cent of the weight of the hurds consists of hemp fiber, in strands from 3 inches to 8 feet in length. Some fragments of the bark, made up of short cubical cells, usually dark in color, cling to the strands of fiber.

CHARACTER OF HURDS AFFECTED BY RETTING.

Nearly all of the hemp in the United States is dew retted. The stalks are spread on the ground in swaths, as grain is laid by the cradle. The action of the weather, dew, and rain, aided by bacteria, dissolves and washes out the green coloring matter (chlorophyll) and most of the gums, leaving only the fibrous bark and the wood. The plants in this process lose about 60 per cent of their green weight, or about 40 per cent of their air-dry weight.

The stalks are sometimes set up in shocks to cure before retting, and after retting they are set up in shocks to dry. Each time the stalks are handled they are chucked down on the ground to keep the butts even. In these operations sand and clay are often driven up into the hollow at the base of the stalks, and this dirt, which often clings tenaciously, may constitute an objectionable feature in the use of hemp hurds for paper stock.

In Italy and in most localities in Russia and Austria-Hungary where hemp is extensively cultivated, it is retted in water, but water retting has never been practiced in the United States except to a limited extent before the middle of the last century. Hurds from water-retted hemp are cleaner and softer than those from dew-retted hemp.

The fiber is sometimes broken from dry hemp stalks without retting. The hurds thus produced contain a small percentage of soluble gums, chiefly of the pectose series. Comparatively little hemp is prepared in this manner in America.

Process retting by means of weak solutions of chemicals or oils in hot water is practiced to a limited extent. The hurds from these processes may contain traces of the chemicals or oils and also soluble gums in greater degree than those of the dew-retted or water-retted hemp.

PROPORTION OF HURDS TO FIBER AND YIELD PER ACRE.

The yield of hemp fiber varies from 400 to 2,500 pounds per acre, averaging 1,000 pounds under favorable conditions. The weight of hurds is about five times that of the fiber, or somewhat greater from hemp grown on peaty soils. A yield of 2½ tons of hurds per acre may be taken as a fair average.

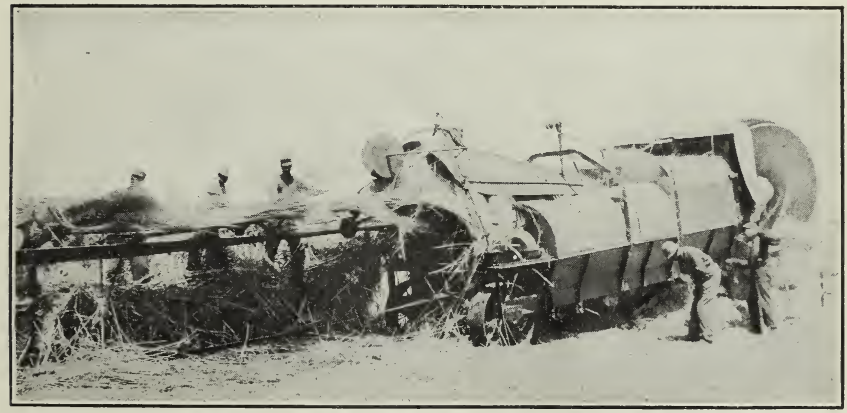

FIG. 1.—Hemp-breaking machine. The stalks are fed sidewise in a continuous layer 2 to 3 inches thick, turning out about 4,000 pounds of clean fiber per day and five times as much hurds.

HURDS AVAILABLE FROM MACHINE-BROKEN HEMP.

Hemp hurds are available only from hemp which is broken by machines, when the hurds may be collected in quantity in one place (figs. 1 and 2). Most of the hemp in Kentucky is still broken by hand brakes. These small brakes are moved from shock to shock, so that the hurds are scattered all over the field in small piles of less than 50 pounds each, and it is the common practice to set fire to them as soon as the brake is moved. It would be difficult to collect them at a cost which would permit their use for paper stock.

Where machine brakes are used, the hemp stalks are brought to the machine as grain is brought to a thrashing machine, and the hurds accumulate in large piles, being blown from the machine by wind stackers.

Machine brakes are used in Wisconsin, Indiana, Ohio, and California, but to only a limited extent in Kentucky. Five different kinds of machine brakes are now in actual use in this country, and still others are used in Europe. All of the best hemp in Italy, commanding the highest market price paid for any hemp, is broken by machines. The better machine brakes now in use in this country prepare the fiber better and much more rapidly than the hand brakes, and they will undoubtedly be used in all localities where hemp raising is introduced as a new industry. They may also be used in Kentucky when their cost is reduced to more reasonable rates, so that they may compete with the hand brake. Hemp-breaking machines are being improved and their use is increasing. The hemp-growing industry can increase in this country only as machine brakes are developed to prepare the fiber. A profitable use for the hurds will add an incentive to the use of the machine brake.

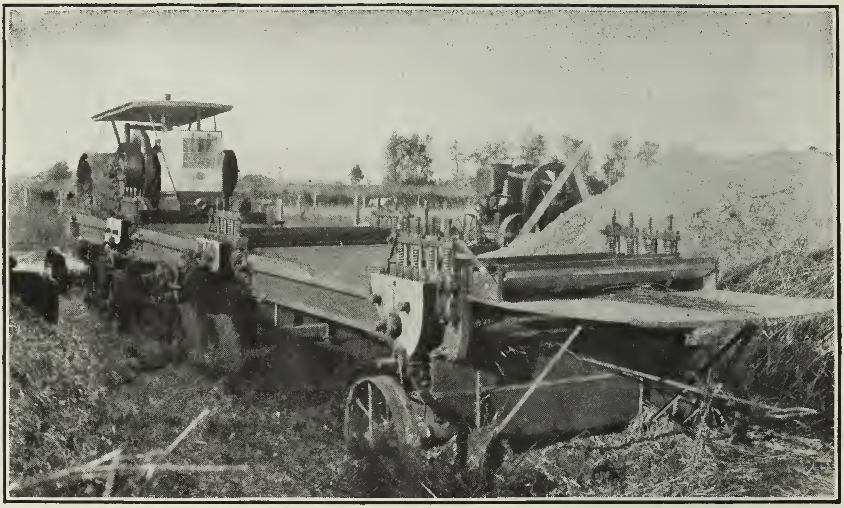

FIG. 2.—Machine brake and hemp hurds. Hemp hurds from machine brakes quickly accumulate in large piles.

PRESENT USES OF HEMP HURDS.

Hemp hurds are used to a limited extent for barnyard litter and stable bedding, as a substitute for sawdust in packing ice, and, in rare instances, for fuel. They are not regarded as having a commercial value for any of these uses, though they are doubtless worth at least $1 per ton on the farm when used for stable bedding. They are a waste product, without value for other purposes which might compete with their use for paper stock.

PRESENT SUPPLIES OF HURDS AVAILABLE.

During the last season, 1915, about 1,500 acres of hemp have been harvested outside of Kentucky and in regions where machine brakes are used. Estimating the yield of hurds at 2½ tons per acre, this should give a total quantity of about 3,750 tons. Large quantities of hemp from the crop of 1914, which are still unbroken in these areas, and large piles of hurds undisturbed where the machines have been used during the last two or three years, increase the total to more than 7,000 tons. Hemp is now grown outside of Kentucky in the vicinity of McGuffey, east of Lima, Ohio; around Nappanee, Elkhart County, and near Pierceton, in Kosciusko County, Ind.; about Waupun and Brandon, Wis.; and at Rio Vista and Stockton, Cal.

In Kentucky, hemp is grown in most of the counties within a radius of 50 miles of Lexington. No accurate statistics of the acreage are collected, but the crop harvested in 1915 is estimated at 7,000 acres. A machine brake will probably be used in Bourbon County and also in Clark County, but most of the hemp in Kentucky will be broken on hand brakes.

BALING FOR SHIPMENT.

The hurds will have to be baled to facilitate handling in transportation and to economize storage space at the paper mills. The bales will need to be covered with burlap or some material to keep them from shaking out. They may be baled in the same presses that are used for baling hemp fiber, but care must be exercised to avoid breaking the press, for the hurds are more resistant than hemp fiber. A bale of hemp 2 by 3 by 4 feet weighs about 500 pounds. A bale of hurds of the same size will weigh about one-third less, or approximately six bales per ton.

Rough hemp fiber as it is shipped from the farm is not covered; therefore, the covering material must be purchased especially for the hurds. A piece of burlap about 36 by 48 inches placed on either side of the bale will be sufficient, but these pieces, weighing about 3 pounds each, cost about 40 cents a pair. Baling rope, in addition to jute covering, will cost at least 5 cents per bale, making the total cost of covering and ties $2.70 or more per ton. Possibly chip board, costing about $33 per ton, or not more than 5 cents for the two pieces for each bale, may be used in place of burlap. Chip board, burlap, and also rope ties may all be used for paper stock. Burlap covers might be returned, to be used repeatedly until worn out, but chip board could not be used more than once.

COST OF BALING.

If burlap covers are used the cost of baling, including covering, ties, use of baling press, power, and labor will amount to at least 60 cents per bale, or about $3.75 per ton. If chip board can be used the cost may be reduced to about $2 per ton. The cost of hauling and loading on the cars will vary from $1 to $3 per ton, depending upon the distance and the roads. The farmer must therefore receive from $4 to $6 per ton for the hurds, baled, on board cars at his home station.

SUMMARY.

Hemp hurds are the woody inner portion of the hemp stalk, broken into pieces in removing the fiber.

They are not used at present for any purpose that would compete with their use for paper.

Hurds are available only from machine-broken hemp, for the cost of collecting them from the hand brakes would be too great.

About 7,000 tons are now available in restricted localities in Ohio, Indiana, Wisconsin, and California.

The quantity is likely to increase as the use of machine brakes increases.

The hurds may be baled in hemp-fiber presses, with partial burlap covers like those on cotton bales, or possibly chip-board covers.

It is estimated that the farmers may deliver the bales on board cars profitably at $4 to $6 per ton.

THE MANUFACTURE OF PAPER FROM HEMP HURDS.

By Jason L. Merrill, *Paper-Plant Chemist, Paper-Plant Investigations.*

INTRODUCTION.

The purpose of this paper is to report upon preliminary tests which were conducted to determine the paper-making value of hemp hurds, a crop waste of the hemp-fiber industry.

The search for plant materials capable of being utilized in paper manufacture is a comparatively recent but world-wide activity which has for its object the husbanding of present sources of paper-stock supply by the substitution of new materials for some of those which are rapidly becoming less plentiful and more costly.

The abstract idea of utilizing that which is at present a waste can play no important rôle in such activities, the successful commercial outcome of which must be based on the three fundamental factors—market or demand for product, satisfactory raw material, and cost.

Since hemp hurds are to be treated in this report as a raw material for the manufacture of book and printing papers, the qualities, supply, probable future, and cost of the material will be considered in comparison with wood, with which it must compete. There seems to be little doubt that the present wood supply can not withstand indefinitely the demands placed upon it, and with increased scarcity economy in the use of wood will become imperative. This effect is already apparent in many wood-using industries, and although the paper industry consumes only about 3 per cent of the total forest cut, it is probable that it will be affected through this economy. Our forests are being cut three times as fast as they grow, and as wood becomes more expensive proper growing and reforesting will receive more attention. Thus, naturally, a balance will be established between production and consumption, but as this condition approaches its limiting values the price of wood may rise to such levels that there will be a demand for other raw materials.

The use of waste paper in conjunction with chemical wood pulp has increased to enormous proportions, and it is probable that the increase will continue. Although it is a cheaper raw material than wood, it is reasonable to suppose that as the wood supply decreases and the price of wood pulp advances, the price of waste paper will advance somewhat proportionately.

In view of these conditions it is advisable to investigate the paper-making value of the more promising plant materials before a critical situation arises. To be of substantial value the investigations should include not only a determination of the quality and quantity of pulp and paper which the material is capable of producing, but should embrace a consideration of such relevant factors as agricultural conditions, farm practice, assembling conditions, transportation, and probable future supply.

Certain cultivated plants seem particularly promising, because in the harvesting of the regular crop that portion which might be utilized for paper manufacture necessarily is either wholly or partially assembled. To this class of plants belong corn, broom corn, sorghum, sugar cane, bagasse, flax, hemp, and the cereal straws.[1]

It is generally conceded that the employment of different raw materials would probably yield products of a somewhat different quality than those now prevailing in the markets, but the qualities of papers and the public demands are so diversified and numerous that this possible objection should not be serious. Ten years ago sulphite manufacturers would not accept consignments of spruce logs if they contained over 5 per cent of fir, while to-day many manufacturers tolerate 50 per cent. Rope papers are found to contain not only jute, but when this raw material is not plentiful, chemical pulp of various kinds. "Linen paper" is often no more than a trade term. Not long ago printing papers were made entirely from chemical wood pulp, but to-day if it is desired to secure paper which is free from ground wood the specifications must so stipulate. Writing papers, formerly made entirely from rags, now are likely to contain either chemical or even ground-wood pulp unless the specifications prohibit it. Without doubt, many paper manufacturers have maintained certain papers up to a fixed standard for a long series of years, but it is equally true that competition has lowered the standard of a great many papers, some of which had acquired a distinctive recognition. The employment of plant fibers will not necessarily lower the present quality of papers, but if their employment does result in products whose qualities are somewhat different from our so-called standard papers it does not necessarily follow that such papers will not find a ready market.

FACTORS JUSTIFYING AN INVESTIGATION OF HEMP HURDS.

Hemp hurds form a crop waste, in that they necessarily are produced in the raising and preparation of hemp fiber, and their present use and value are comparatively insignificant.

The assembling of the hurds may be effected with economy, since the area in which hemp is handled with the use of machine brakes is restricted. Although it must be stated that the present annual supply would not be sufficient to justify the installation of a pulp mill nor would its transportation to existing mills appear feasible, it is expected that the available annual tonnage, especially in certain general sections, will increase, due to the increased use of the machine brake. The present tonnage per annum is approximately as follows: In the region of Ohio and Indiana, 2,500 tons; in the Wisconsin section, 1,000 tons; in the California region, 1,400 tons.

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[1] For descriptions of investigations of some of these crops, see the list of publications at the end of this bulletin.

In years of adverse weather conditions there are often large areas of hemp which are not harvested on account of its poor quality; there are also large areas of cut hemp which become overretted, due to inclement weather. It has been suggested by some of the hemp raisers that this large amount of material might be utilized as a paper stock. In these cases the cost of the whole material would probably be somewhat higher than that of the hurds, because either all or part of the cost of harvesting and the total cost of breaking would have to be borne by the paper maker. Moreover, the quality of this material would be so very irregular and the supply so uncertain that it probably would not appeal to the paper manufacturer.

Without doubt, hemp will continue to be one of the staple agricultural crops of the United States. The wholesale destruction of the supply by fire, as frequently happens in the case of wood, is precluded by the very nature of the hemp-raising industry. Since only one year's growth can be harvested annually the supply is not endangered by the pernicious practice of overcropping, which has contributed so much to the present high and increasing cost of pulp wood. The permanency of the supply of hemp hurds thus seems assured.

The favorable location geographically of the hemp regions in relation to the pulp and paper industry is a factor of considerable importance. The Kentucky region is not at present in a position to supply hurds, as machine methods have not been adopted there to any appreciable degree. The Ohio and Indiana region, which at present has the greatest annual tonnage, with the prospect of an increase, is situated south of the Wisconsin and Michigan wood-pulp producing region and at a distance from the eastern wood-pulp producing regions; therefore, it is in a favorable position to compete in the large Ohio and Indiana markets. Since, as will be shown, the hurd pulp acts far more like soda poplar stock than sulphite stock, competition would be strongest from the eastern mills; in fact, the hurd stock might very possibly meet with favor as a book-stock furnish in the Michigan and Wisconsin paper mills, which are within the sulphite fiber-producing region. Because of its very close proximity to paper mills, this latter possibility applies with far greater force to the Wisconsin hemp region, where a considerable extension of the hemp industry is anticipated.

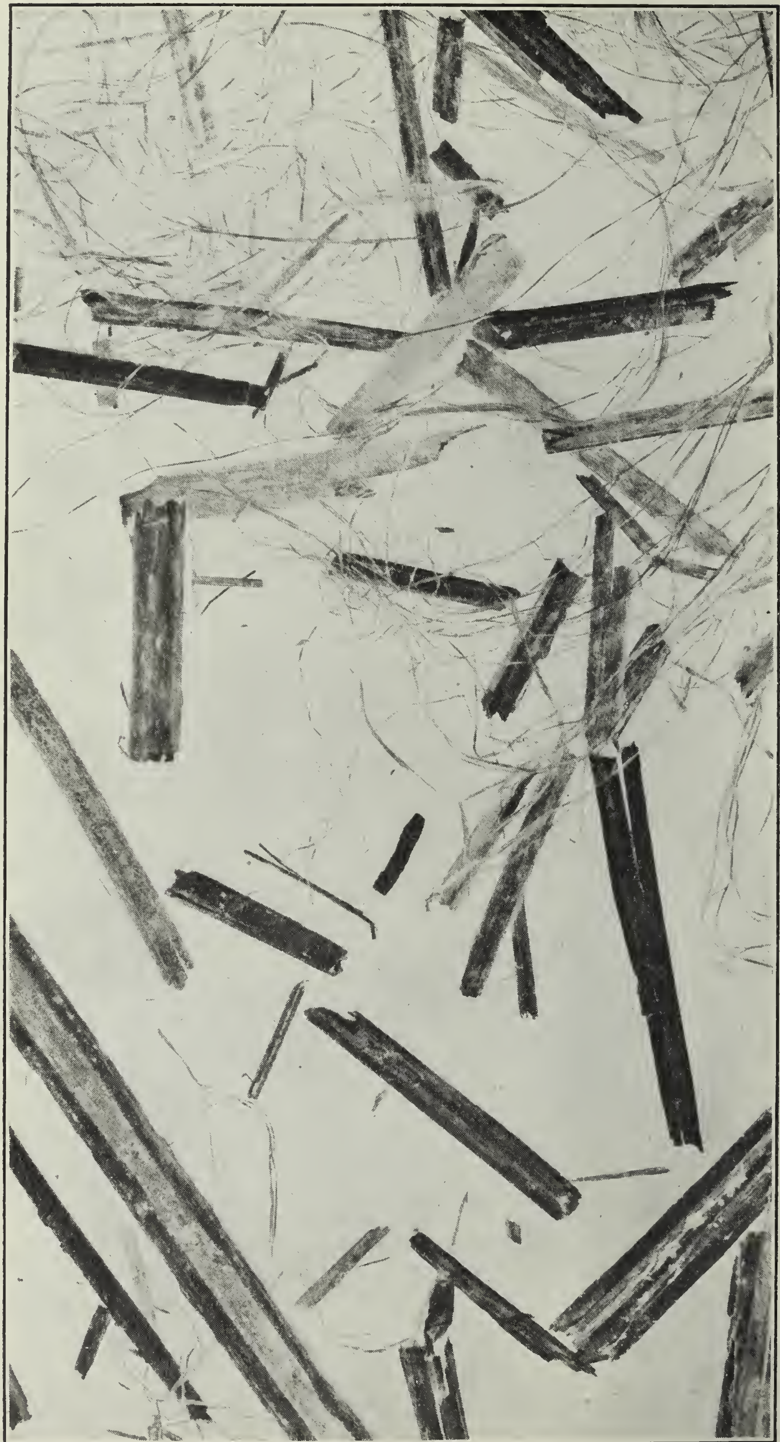

FIG. 3.—A representative sample of hemp hurds, natural size, showing hemp fiber and pieces of wood tissue.

CHARACTER OF THE MATERIAL.

As received from Pierceton, Ind., the hurds consisted of a mixture of tangled hemp bast fibers and pieces of broken wood of the hemp stalk. (Fig. 3.) No reliable data were secured as to the proportion of bast fiber in the total shipment of 4 tons, although two hand separations of small representative samples gave results averaging 8 per cent. The chemical character of the material was such and the quantity was so small that any appreciable variation of the proportion should not affect materially the treating processes finally adopted, yet its presence in varying proportions undoubtedly would modify to some extent the quality of the resulting paper product. Since the length of the ultimate bast fiber averages about 22 mm. and the length of the ultimate hemp wood fiber averages 0.7 mm., it is natural to assume that the bast fiber would tend to increase the strength of paper produced from the hurds. (Fig. 4.)

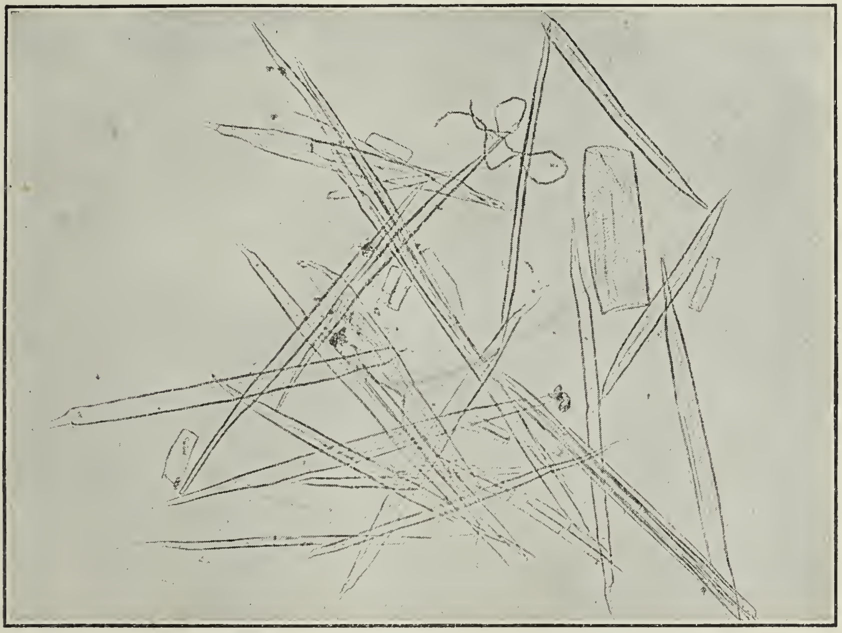

Fig. 4.—Fiber derived from the woody portion of the hurds. × 75. From a microphotograph.

The broken pieces of wood contained in the hurds varied in length from mere particles which were somewhat finer than sawdust to pieces about 3½ inches long, exceptional pieces being found which measured 6 inches in length. The majority of the long pieces were between 2 and 3 inches in length. In thickness the pieces ranged from one-eighth of an inch, in case they were derived from the base of the hemp stalks, to about one sixty-fourth of an inch in those pieces which were derived from the top and branches of the stalks. In cross section the pieces often were found to be a quarter or half of the rounded rectangular woody shell of the stalk, although there appeared to be no regularity in this respect.

From the pulp-maker's standpoint the great irregularity in thickness, length, and mass of the woody pieces militates decidedly against economy in pulp production. The smaller pieces reduce by chemical treatment sooner than the larger fragments and are thereby overtreated, which results in a lower yield of cellulose fiber and a product composed of undertreated and overtreated fibers, the production and use of which are not satisfactory or economical. It probably would be found more satisfactory, therefore, to screen or sort the hurds and treat the various sizes separately and differently.

Associated with the hurds was a small quantity of chaff and dirt, composed chiefly of sand, soil, particles of hemp leaves and flowers, and other extraneous matter. The sand and soil were present because of the practice of placing the stalks in shocks in the field, the butts of the stalks being in contact with the soil. It is a simple matter, however, to remove the chaff and dirt by sieving, and this practice was followed in most of the paper tests conducted with this material.

CHARACTER OF THE TESTS.

Because of the similarity of hemp hurds to other materials which have been tested by the Office of Paper-Plant Investigations, semicommercial tests were conducted in cooperation with a paper manufacturer without preliminary laboratory tests. Laboratory pulp and paper tests are regarded only as a preliminary to semicommercial tests and therefore are not employed unless the material in question presents new features which should receive investigation before larger sized tests are undertaken.

The advantages of cooperative mill tests are many, among which may be mentioned the counsel and advice of the mill management and employees, the services of specialized and skilled labor, facilities for comparing the processes and the results of tests with commercial processes and results, and the use of commercial or semicommercial types and sizes of machinery. Tests conducted in this manner and on this scale are of a different quality than is possible in those conducted in a laboratory, and the results are susceptible of commercial interpretation with a fair degree of reliability. It is found, in general, that the cost of securing such equipment and service for a complete and comprehensive test does not exceed $500, while the installation of an equally satisfactory equipment alone would cost at least $50,000 and in many cases very much more. Tests conducted in this manner constitute a direct demonstration to the manufacturer, and the results obtained are found to carry more weight when presented to other manufacturers for consideration.

It is well known that the method of conducting tests necessarily varies with the size of the test. In the matter of yield determination, for example, laboratory tests may be on such a small scale that the weighing and sampling of the resulting cellulose fibers may be conducted by means of chemical laboratory apparatus and analytical balance, while in tests involving a matter of 5 to 10 pounds of material larger and different types of equipment are necessary. When the tests are so increased in size as to employ 300 or 400 pounds, still other types of equipment are necessary for the treatment of the material and for a determination of the yield of fiber. In tests involving tons of material the equipment involves the use of machines. Accuracy in degree of control and in results will vary materially with the size of the test. As the size of the test increases, certain factors will vary in a beneficial manner, while others will vary in a detrimental manner, so it is a question for each investigator to decide, after taking all factors into consideration, as to the size of test which will give the most satisfactory results. In work of this nature it is found, on the whole, that better results are obtained in large tests, although the control of the factors and the determination of the yield of fiber are more difficult than in smaller tests.

In the tests described in this bulletin, the Department of Agriculture employed a rotary digester of its own design,[1] comprising a shell 5 feet 5 inches in length by 4 feet in diameter, capable of holding about 300 pounds of air-dry hurds. It is believed that a test of this size is large enough to give satisfactory results and that the results are susceptible of commercial interpretation, while at the same time they are sufficiently small for complete control and to afford fiber-yield figures which are both accurate and reliable. Two such rotary charges gave enough fiber for one complete paper-making test.

OPERATIONS INVOLVED IN A TEST.

A complete test on hurds comprises seven distinct operations, and the method will be described, operation by operation, in the order in which they were conducted.

Sieving.—The hurds for the first test were not sieved to remove sand and dirt, but the resulting paper was so dirty that sieving was practiced in all subsequent tests. The hurds were raked along a horizontal galvanized-iron screen, 15 feet long and 3 feet wide, with 11½ meshes per linear inch, the screen being agitated by hand from below. Various amounts of dirt and chaff could be removed, depending on the degree of action, but it was found that if much more than 3 per cent of the material was removed it consisted chiefly of fine pieces of wood with practically no additional sand or dirt; in most of the tests, therefore, the material was screened so as to remove approximately 3 per cent. It became apparent that a finer screen would probably serve as well and effect a saving of small but good hurds.

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[1] For a description of this rotary digester, see Brand, C. J., and Merrill, J. L., Zacaton as a paper-making material, U. S. Dept. Agr. Bul. 309, p. 28, 1915.

Cooking.—Cooking is the technical term for the operation by which fibrous raw materials are reduced to a residue of cellulose pulp by means of chemical treatment. In these tests about 300 pounds of hurds were charged into the rotary with the addition of a caustic-soda solution, such as is regularly employed in pulp mills and which tested an average of 109.5 grams of caustic soda per liter, or 0.916 pound per gallon, and averaged 85 per cent causticity. Sufficient caustic solution was added to furnish 25 or 30 per cent of actual caustic soda, calculated on the bone-dry weight of hurds in the charge. After closing the rotary head, it was started rotating at the rate of one-half revolution per minute, and in about five minutes steam at 120 pounds per square inch was admitted at such a rate that the charge was heated in one hour to 170° C., which is the theoretical equivalent of 100 pounds of steam pressure per square inch. It was found, however, that when the temperature reached 170° C. the pressure was usually 115 or 120 pounds instead of 100 pounds, due to air and gases inclosed in the rotary. At this point the rotary was stopped and steam and air relieved until the pressure dropped to 100 pounds, or a solid steam pressure. The temperature was maintained at this point for the number of hours required to reduce the hurds, which was found to be about five, after which the rotary was stopped and steam relieved until the pressure was reduced to zero, when the head was removed and the stock was emptied into a tank underneath, measuring 5½ by 6 by 2 feet deep, where it was drained and washed. Samples of waste soda solution or "black liquor," which were taken from some of the "cooks" for analysis, were drawn while the stock was being thus emptied into the drainer.

Determination of yield.—For determining the yield of cellulose fiber the stock in the drain tank was washed with water until free from waste soda solution, when, by means of a vacuum pump communicating with the space between the bottom and the false perforated bottom, the water was sucked from the stock, leaving the fiber with a very uniform moisture content throughout its entire mass and in a condition suitable for removing, sampling, and weighing for a yield determination. Tests have shown that it is possible to sample and calculate the yield of bone-dry fiber within 0.05 per cent of the actual amount.

It has been found that stocks from different materials vary greatly in their ability to mat in the drain tank, thereby enabling a good vacuum to be obtained, some stocks permitting a 25-inch vacuum to be obtained, while others will not permit more than 5 inches. For this reason the moisture content of the stock will vary from 65 to 85 per cent.

Washing and bleaching.—Washing and bleaching were performed for the purpose of bleaching the brown-colored cooked stock to a white product, since it was regarded as highly probable that the fiber would be suitable for book-paper manufacture. The colored stock was charged into a 400-pound beating and washing engine of regular construction and washed about one hour, the cylinder washer being covered with 60-mesh wire cloth in order to remove fine loose dirt and chemical residues. The washer was then raised, the stock heated by steam to about 40° C., and a solution of commercial bleaching powder was added in the quantity judged to be necessary, after which the stock was pumped to a large wooden tank, to remain and bleach over night. If the stock was bleached sufficiently white it was drained and washed from bleach residues, and if not more bleach was added until a good color was obtained. The bleaching powder used was estimated to contain 35 per cent of available chlorin, as this is the commercial practice, and the amount required was calculated to the bone-dry weight of the unbleached stock. More bleach is required for undercooked stock than for stock which is properly cooked or overcooked; therefore, the percentage of bleach required is an indication of the quality of the cooked stock. Since bleaching is usually more expensive than cooking, it is desirable to cook to such a degree that the consumption of bleach will be held within certain limits, depending on the raw materials used and the quality of paper to be produced. In these tests it was desirable so to cook the hurds that the consumption of bleach would not be over about 10 per cent of the fiber.

Furnishing.—Furnishing is the operation of charging the beating engine with the desired kind or kinds of fiber in the proper proportion and amount and the adding of such loading and sizing agents as may be necessary. As shown in the record of results, the furnish in these tests consisted of hurd stock alone and of various proportions of hurds, sulphite fiber, and soda fiber. The percentages to be given in the record of the furnishes refer to the percentage of the total fiber furnish, and this likewise applies to the loading and sizing agents. In case sulphite or soda fiber was used, the commercial product in the dry state was charged into the beating engine and disintegrated, after which the hurd stock was added in the wet condition.

Beating.—Beating is that operation concerning which the paper makers often say "there is where the paper is really made," and although the statement may not be literally true it contains a great deal of truth. It is the operation whereby the fibers are separated from each other, reduced to the proper lengths, and put in such a physical or chemical condition that they felt properly and form into a satisfactory sheet. It is probable that the quality of the sheet depends more upon the proper beater action than upon any other single operation. The action consists in drawing a water suspension of the fiber between two sets of rather blunt knives, one set being located in the bottom of a circulating trough and the other set on the periphery of a roll revolving just above the former set of knives. It is during this operation that the loading and sizing agents are incorporated and the whole furnish is tinted either to produce a satisfactory white or the desired color.

The term "paper making," as used in this publication, means the operation of forming the finished sheet of paper from stock which has been furnished and prepared in the beater. In these tests a 30-inch Fourdrinier machine of regular construction was used, a machine which often is used for the production of paper for filling regular commercial orders. The machine is designed to cause the water suspension of fibers to flow on to a traveling wire cloth, whereby the water drains away. More water is removed by passing the wet sheet through a series of press rolls, after which the sheet is dried on steam-heated drums and passed through polished iron rolls, which impart a finish to the sheet. A Jordan refining machine was employed in conjunction with the machine to improve further the quality of the fiber, and a pulp screen was used in order to remove coarse and extraneous materials from the fiber.

DESCRIPTION OF TESTS.

The nature of each complete paper test and the dependence of each operation on the others were such that it does not seem advisable to submit the results of the seven tests in tabular form. The numerous cooks, however, which furnished the pulp for the paper tests are presented in Table I in all essential detail.

TABLE I.—*Data on cooking hemp hurds.*

Cook No.	Caustic soda used (percentage of bone-dry hurds).	Strength of caustic soda (grams per liter).	Causticity of soda solution.	Cooking.		Yield of bone-dry fiber (percentage of bone-dry unsieved hurds).
				Time (hours).	Temperature (°C.)	
293	20.6	100	75.3	3	166	....
294	21	100	75.3	3	166	....
295	21.6	100	75.3	3	166	....
296	20.3	100	75.3	3	166	....
301	21.9	100	82.5	4	166	(1)
302	24.4	100	82.5	4	166	....
303	24.2	100	84.3	4	166	44.1
304	25	100	84.3	4	170	39.5
305	25	100	84.3	5	170	39.4
306	27.8	107.5	84.3	4	166	36.5
307	26.7	107	84.4	5	170	38.1
308	26	107	84.4	5	170	37.3
309	27.3	107	84.4	5	170	
310	27.1	107	84.4	6	170	37.0
311	27.2	107	84.4	6	170	36.8
312	28.3	116.5	85.5	5	170	35.9
313	29.1	113.1	84.9	5	170	35.2
314	29.1	109	83.9	5	170	
315	29.4	109	83.9	5	170	34.9
316	30	109.5	84.9	5	170	37.2
317	29.6	109.5	84.9	5	170	37.0
318	29.6	107	84.8	5	170	37.7
319	29.4	107.5	84.2	5	170	35.4
320	29.3	107.5	84.2	5	170	

[1] Stock not used; dirty.

Discussion of the various cooks will be given in connection with the descriptions of those paper tests in which the stocks from the cooks were used, since a stock and its cooking condition can be judged adequately only after it has been put through the various processes and into the finished sheet of paper.

The first test consisted in making four separate cooks, Nos. 293, 294, 295, and 296, of approximately 300 pounds each, dividing the total stock into two parts and making two separate paper tests. The first test was made primarily in order to learn some of the qualities and characteristics of the stock and to get the machinery equipment adjusted properly. The yield of fiber was not determined in this preliminary test, since the knowledge of it was not essential at this stage of the work. The cooked stock which was emptied into the drainer to be washed free from black liquor was composed largely of whole pieces of hurds, but only slight pressure between the fingers was required to crush the pieces. In the case of wood, this condition ordinarily would indicate undercooking, but might not in the case of hurds. Further observation on the action of the cooked stock during subsequent processes was necessary in order to judge of its quality or the suitability of the cooking conditions. The total cooked stock, about 500 pounds, was divided into two portions of 200 and 300 pounds, respectively, and work was continued on them separately. The 200-pound test, designated as run No. 135, was put into a 350-pound washing engine, washed one hour, and given a total light brush of 2¼ hours. The washing removed a great amount of dirt, but the engine did not reduce the hurd stock as much as was desired. After heating the stock in the beater to 40° C., it was bleached with bleaching-powder solution, 94 gallons at 0.418 pound bleach per gallon, equivalent to 19.7 per cent of the fiber. This percentage of bleach is regarded as too high for stock intended for book-paper manufacture, and subsequent cooks therefore were given harder treatment in order to reduce this figure. After draining and washing free from bleach residues, the stock was furnished in the beater with 13 per cent of clay, 1 per cent of resin size, and 2.5 per cent of alum, was tinted blue, given one hour's light brush, and pumped to the stock chest. When running it on the paper machine, the Jordan refiner seemed to have little effect in reducing shives of undertreated wood, which indicated further the necessity of harder cooking. The furnish acted well on the paper machine at 70 feet per minute, but appeared somewhat too "free" on the wire. The paper produced from this test is of very low quality, due to the improper preparation of the stock, lack of sufficient bleach, the use of too small an amount of blue tinting, and the presence of an excessive amount of dirt, sand, and shives. The excessive amount of dirt and sand suggested the sieving of the hurds before cooking, and this was performed in all subsequent cooks.

The finish of the sheet is very poor, due to the fact that the calender stack was composed of very light rolls which did not have a satisfactory surface, yet the stack is known to be able to produce better finishes if the proper stock is employed.

Run No. 136 was made on the 300-pound portion of stock from cooks Nos. 293, 294, 295, and 296, and in essentially the same manner as run No. 135. The stock was washed one hour, but given a brush of three hours, and this brush was harder than in run No. 135. Bleach to the extent of 19.8 per cent of the fiber was used, assisted by 1 pint of oil of vitriol, and the resulting color was an improvement over that of run No. 135. After adding 13.5 per cent of clay and sizing with 1.1 per cent of resin size, the furnish was given one-half hour's light brush, tinted, and run on the machine, which was set at 70 feet per minute. This stock acted better on the wire and gave no trouble on the machine, but it still seemed to be impossible to reduce the wood shives by manipulation of the Jordan refiner. The resulting sheet is an improvement over that produced by No. 135, but is far from satisfactory.

Run No. 138 was made from hurds which, as in all subsequent tests, were sieved on a 11½-mesh wire screen until practically all the loose dirt and sand was removed, which operation caused a loss averaging 3 per cent of the hurds. Stock from cooks Nos. 302 and 303 was used for this run and the increased amount of caustic soda and the increase in the time of cooking gave a stock of better appearance than those of preceding tests.

The stock, amounting to 231 pounds dry weight, was washed and at the same time given a light brush for one hour only, after which it was bleached with 17 per cent of bleach without the addition of acid. Since the preceding paper appeared somewhat weak and had a low tearing quality, it was decided to use a furnish of 15.7 per cent bleached sulphite and 84.3 per cent bleached hemp-hurd stock. After loading with 13.1 per cent of clay and sizing with 1.1 per cent of resin size, the furnish was given a medium brush for one hour, tinted, and run on to the machine at 70 feet per minute. The stock gave no trouble on the machine, but it was impossible to judge the effect of the Jordan refiner, because through an oversight the machine chest had not been cleaned since previous use on an unbleached yucca material. It is believed, however, that sheet No. 138 shows improvement in the preparation of the hurd pulp.

Run No. 139 was made from stock of cooks Nos. 304 and 305, in which still more caustic soda was employed and the time and temperature of cooking were increased, giving a yield of total fiber of 40.7 per cent of the sieved or 39.4 per cent of the unsieved hurds. The cooked stock still seemed to be undertreated, but it must be remembered that in working with any new raw material it is impossible to know in advance how the properly treated material should appear. A washing of one hour was given while the roll was lowered from a light to a medium brush, after which the stock was bleached with 17.1 per cent of bleach without the aid of acid. Since sulphite stock improved the previous paper, this bleached stock was used in a furnish of 16.6 per cent sulphite and 83.4 per cent hurds, loaded with 16.7 per cent clay, sized with 1.4 per cent resin size, given a medium brush of two hours, tinted, and run on to the machine at 70 feet per minute. The Jordan refiner seemed to have little effect in reducing shives and was therefore left "just off." No trouble was experienced with the stock on the machine, and the sheet is an improvement over previous samples.

Run No. 140 was made from cooks Nos. 306 and 307, in which more caustic soda was employed than in any previous cooks and at a higher concentration, the fiber yields of which averaged 37.3 per cent of the unsieved hurds. Not much improvement was apparent in the cooked stock, in spite of the increased severity of cooking. The stock was washed and given a medium brush for one hour, bleached with 11.9 per cent of bleach, assisted with one-half pint of oil of vitriol, and made into a furnish of 14.9 per cent sulphite and 85.1 per cent of the hurd stock. After loading with 14.7 per cent of clay and sizing with 1.28 per cent of resin size, the furnish was given two hours' medium brush, tinted, and run on to the paper machine at 70 feet per minute. Again the Jordan refiner did not seem to reduce the wood shives sufficiently, and it was left "just off." No trouble which could be attributed to the stock was experienced on the paper machine. The color of the resulting paper is due to the use of too little blue in tinting and probably in some measure to the use of too low a percentage of bleach.

Run No. 141 was made from the stock of cooks Nos. 308 and 309 in practically the same manner as run No. 140. The stock was washed and brushed one hour, bleached (the record of the amount of bleach was lost), made into a furnish of 14.7 per cent of sulphite and 85.3 per cent of hurd stock, loaded with 14.9 per cent of clay, sized with 1.26 per cent of resin size, given one hour at a medium brush, tinted, and run on to the machine. The Jordan refiner was able to reduce the wood shives to a somewhat greater degree than in previous runs and was held at a medium brush. The stock acted well on the machine and produced a sheet of better quality than any preceding, with the exception of the color, which was due to using too small a quantity of blue.

Among the cooks made for run No. 142 are Nos. 312 and 313, in which the concentration of the caustic soda was raised to 113 and 116 grams per liter and the percentage employed was also increased. In spite of these increases the stock from these two cooks did not show any appreciable improvement when dumped from the rotary. Stock from cooks Nos. 310, 311, and 312 was given a medium brush and washing of one hour, bleached with 10.95 per cent of bleach, made into a furnish consisting of 15.2 per cent of sulphite and 84.8 per cent of hurd stock, loaded with 15.2 per cent of clay, sized with 1.28 per cent of resin size, given a medium brush for one hour, tinted, and pumped to the stock chest. Stock from cooks Nos. 313 and 314 was treated in exactly the same manner, except that 11.4 per cent of bleach was used. It was pumped to the stock chest and mixed with the furnished stock from cooks Nos. 310, 311, and 312. A medium Jordan brush was given the stock and it acted well on the paper machine, which was speeded to 75 feet per minute. There seems to be a tendency in the hurd stock to crush a little at the "dandy roll," and although the marks are not removed by the calender stack which was employed in those tests it was found that one "nip" on the supercalenders renders them practically imperceptible and it is believed that the proper size and weight of calender stack would entirely remove these marks. All of the papers produced up to this point are somewhat lacking in the bulk desired in a book paper; therefore, in the two following runs soda-poplar stock was included in the furnishes.

In run No. 143 stock from cooks Nos. 315 and 316 was given a medium brush and washing for one hour and was medium brushed for one hour more, bleached with 11.3 per cent of bleach assisted with one-half pint of oil of vitriol, made into a furnish of 16.5 per cent of sulphite, 22.3 per cent of soda poplar, and 61.2 per cent of hurd stock, loaded with 22 per cent of clay, sized with 1.38 per cent of resin size, given a hard brush for one hour, tinted very strongly, and pumped to the stock chest. This stock was beaten to a greater extent than in previous runs. The stock was run on the paper machine at a speed of 75 feet per minute, using a medium Jordan brush, and no trouble whatsoever was experienced. Not over 2 pounds of "broke" was produced during the whole run, and that was in the "threading" of the machine. The color of the sheet is entirely satisfactory for many uses. The wood shives apparently were reduced to a satisfactory degree. Experienced paper makers commented very favorably on the running of this furnish and the quality of the paper produced.

Run No. 144 was intended as a duplicate of run No. 143. Stock from cooks Nos. 317 and 318 was given a medium brush and washing for one hour and a further medium brush of one hour, bleached with 11.4 per cent of bleach, and made into a furnish composed of 15.5 per cent of sulphite, 23.5 per cent of soda poplar, and 61 per cent of hurd stock, loaded with 21.4 per cent of clay, sized with 1.17 per cent of resin size, hard brushed for one hour, tinted by the expert colorer of the company, and pumped to the stock chest. Stock from cooks Nos. 319 and 320 was treated in exactly the same manner except that the stock was bleached with 12.1 per cent of bleach and pumped to the stock chest to mix with the former furnish. The stock acted very well on the machine, which was speeded to 75 feet per minute, with the Jordan refiner set at a medium brush. The sheet is as good, if not better, than that of run No. 143, and it is also a good illustration of the extent to which proper tinting will enhance the general appearance of a paper. The poor appearance of the samples of previous runs is due largely to lack of proper tinting. Various degrees of whiteness, however, are demanded by the trade.

COMPARISON OF THE TESTS AND COMMERCIAL PRACTICE.

In work of this nature and on this scale it is practically impossible to arrive at a cost figure which would be susceptible of commercial interpretation, and in this preliminary publication nothing will be attempted beyond a comparison of the process used with the hurds with that process commercially applied to poplar wood. The process last used with the hurds should not be regarded as final, satisfactory, or most suitable, as it has been shown that progress was being made up to the conclusion of the work.

In comparing the method of using hurds with the method of handling poplar wood, a difference is apparent on the delivery of raw material at the mill. Ordinarily, poplar is received at the mill in the form of logs about 4 feet in length, which may be stored in piles in the open. Hurds very likely would be received baled, and it would seem advisable to store them under cover for the following reasons: (*a*) Baled hurds would probably absorb and retain more water during wet weather than logs of wood, thereby causing excessive dilution of the caustic liquor; (*b*) prolonged excessive dampness might create heating and deterioration unless the hemp were properly retted; (*c*) wet hurds could not be sieved free from sand and chaff. Should further work show that the first two reasons need not be taken into consideration, the third objection might be overcome by sieving the hurds before baling. Even then, it is probable that baled hurds stored in the open would accumulate and retain considerable dirt from factory chimneys, locomotives, and wind. Checked pulp wood exposed in the open invariably suffers from these causes.

In the preparation of the raw material for the digesters there is likewise considerable difference between hurds and poplar wood. The former apparently requires only a moderate sieving to remove sand and chaff, which operation doubtless would require only a small amount of labor and the installation of some simple machinery of low power consumption. In preparing poplar for digestion, the

4-foot logs are chipped by a heavy, comparatively expensive chipper of high power consumption, after which the chips are sorted by sieving, the large pieces being rechipped. There would be a noteworthy difference in the installation, operating, and depreciation costs of the two equipments, and this difference would counterbalance to a considerable extent the difference in cost of raw material storage.

It is possible that in the use of the chip loft more care would have to be exercised in using hurds because of the tendency of the bast fiber to cause lodgments, but this should not be considered a serious difficulty.

The weight of hurds which are capable of being charged into a rotary is a decidedly unfavorable factor. The weight of a cubic foot of hurds varies somewhat with the proportion of bast fiber, but averages about 5.4 pounds, which, compared with a cubic foot of poplar chips at 8.93 pounds, represents a digester charge of 60.5 per cent of the weight of a poplar-wood charge, or, in terms of fiber capacity, the hurds charge would yield 38.6 per cent as much fiber as the wood charge. The hurds upon being baled for transportation may be broken and crushed to such a degree that the weight of the charge may be increased, and it might be found possible to increase the charge weight by steaming or by the employment of tamping devices. This small weight of charge constitutes one of the most serious objections to the use of hurds in paper manufacture.

In those tests in which the most satisfactory results were obtained, the cooking conditions were 29.5 per cent of caustic soda at a concentration of 107 grams per liter and a causticity of 84.0 per cent acting at a temperature of 170° C. for five hours, or a total time of seven hours. The steam condensation in the rotary used for these tests was abnormally high, due to the fact that the steam supply pipe was uncovered for a considerable distance and the rotary was entirely uncovered. It is believed, therefore, that a larger amount of caustic was necessary than would otherwise have been the case. This belief is strengthened by the quality of the waste liquor from one of the later cooks, which gave on analysis 16.85 grams per liter of free caustic soda and showed a causticity of 27.75 per cent. These data show that only 67.3 per cent of the total caustic employed was actually consumed in the cooking operation, which percentage is lower than obtains in practice. The stock from this cook was bleached with 11.5 per cent of bleach. But even as the figures stand, the comparison with poplar cooking practice is as follows: 29.5 per cent caustic soda used as against 22 to 25 per cent; 107 grams per liter as against 100 to 110; 84 per cent causticity is little different than obtains in practice; 170° C. is about commercial practice; five hours at pressure as against four to six hours; seven hours' total time as against possibly six to eight hours; 11.5 per cent bleach as against 8 to 10 per cent. Thus, it is evident that the cooking conditions employed were slightly more severe and expensive than those in commercial use with poplar wood.

The yield of total fiber obtained from the hurds may be placed at 35 per cent of bone-dry fiber calculated on the bone-dry weight of hurds used, or 33.1 per cent of air-dry fiber calculated on air-dry hurds. The yield of bleached fiber was not determined in this preliminary work, but may be safely estimated as 30 per cent, which is low when compared with a yield of about 47 per cent of bone-dry bleached fiber from bone-dry poplar wood. It is believed quite possible that satisfactory cooking conditions may be found which will give a higher yield than was obtained during these tests. The stock should be classed as easy bleaching, and 11.4 per cent of bleach is a satisfactory figure, although a little high.

As to beating cost, in the last two and most satisfactory tests the total washing and beating time was three hours, which may be about an hour more than ordinarily is used in making papers of this grade, although the practice varies to a considerable extent.

In regard to furnish, there is such a diversity of practice that it is difficult to make a comparison, but if the hurd stock can be produced as cheaply as soda-poplar stock, the furnish used in these last two tests should be regarded as satisfactory to the book and printing paper manufacturer.

The finish of the paper was not all that might be desired, but that was due almost entirely to the calender stack available for the work, which was composed of nine light rolls, many of which were about 6 inches in diameter and which had not been reground for some time. From a small test on a large calender stack it was readily shown that the paper produced is capable of taking a satisfactory finish.

This comparison, satisfactory in many respects, develops two factors which are decidedly unfavorable to hemp hurds, namely, raw-material storage and digester capacity, and they must be taken into full account in considering the paper-making value of this material, although it should be recognized that investigation may result in the material improvement of these conditions. Moreover, it is not at all improbable that further investigation would develop more satisfactory treating conditions and more suitable furnish compositions, and the belief in this possibility is strengthened by the fact that material progress was being made at the conclusion of this preliminary work.

Calculations on the raw material and acreage for a permanent supply for a pulp mill producing 25 tons of fiber a day for 300 days per annum, or 7,500 tons per annum, give the comparison between hurds and wood shown in Table II.

TABLE II.—*Comparison between wood and hemp hurds.*

Material.	Pulp yield.	Raw material required per year.	Annual growth per acre.	Acres required for sustained supply.	
				For 25-ton mill.	For 1 ton of fiber per year.
Wood	Two cords yield 1 ton of fiber.	15,000 cords	0.37 cord (about 0.55 ton).	40,500	5.4
Hemp hurds	One ton yields 600 pounds of fiber.	25,000 tons	2.5 tons	10,000	1.33

The most important point derived from this calculation is in regard to areas required for a sustained supply, which are in the ratio of 4 to 1. Every tract of 10,000 acres which is devoted to hemp raising year by year is equivalent to a sustained pulp-producing capacity of 40,500 acres of average pulp-wood lands. In other words, in order to secure additional raw material for the production of 25 tons of fiber per day there exists the possibility of utilizing the agricultural waste already produced on 10,000 acres of hemp lands instead of securing, holding, reforesting, and protecting 40,500 acres of pulp-wood land.

The annual growth per acre, although decidedly in favor of hurds, has little bearing on the project, because the utilization of the hurds is subordinate to the raising of hemp, and the paper manufacturer probably could afford to use only hurds resulting from the hemp industry.

PHYSICAL TESTS OF THE PAPERS PRODUCED.

Samples of paper produced in the seven tests were submitted to the Leather and Paper Laboratory of the Bureau of Chemistry. The report of that bureau on its tests is given in Table III.

TABLE III.—*Report of the Leather and Paper Laboratory of the Bureau of Chemistry on papers manufactured from hemp hurds.*

Laboratory No.	Run No.	Ash.	Weight of 500 sheets.		Thickness, 1/10000.	Strength (Mullen).			Strength factor (25 by 40, 500).	Folding endurance.	
			25 by 38.	25 by 40.		Average.	Maximum.	Minimum.		Longitudinal.	Transverse.
		Per ct.	*Pounds.*	*Pounds.*							
31570	144	13.9	48	50½	33	15.0	17.0	11.0	0.30	5	3
31571	143	14.5	49	51½	35	14.0	14.0	13.0	.28	4	4
31572	142	9.5	49½	52	33	19.0	20.0	19.0	.37	8	6
31573	141	10.9	48	50½	38	16.5	18.0	11.0	.33	10	8
31574	140	11.4	42	44	30	14.5	16.0	13.0	.33	7	6
31575	139	13.4	55	58	40	19.5	20.0	17.0	.34	8	5
31576	138	10.4	56	59	40	20.0	20.0	19.0	.34	23	15

There is no system of numerically recording the general appearance and "look through" of a paper, but it can be stated that only papers

Nos. 143 and 144 are satisfactory in these respects, the other samples being more or less thickly specked with shives. The general character and tests of these papers correspond very closely with No. 1 machine-finish printing paper, according to the specifications of the United States Government Printing Office, which call for a sheet not exceeding 0.0035 inch in thickness, strength not less than 12 points, free from unbleached or ground wood pulp, and ash not over 10 per cent. The strength factor of such papers is about 0.28. The ash should not be over 10 per cent for this grade of paper, but in spite of the larger amount used the physical tests are sufficiently high. It is to be noted that the physical tests of samples Nos. 138 to 142, inclusive, are higher than in Nos. 143 and 144, in which 23 per cent of soda poplar was used, which shows clearly that hemp-hurd stock imparts strength and folding endurance to a greater extent than does soda-poplar stock. From these preliminary tests it would be concluded, therefore, that hemp-hurd stock acts similarly to soda-poplar stock, but will produce a somewhat harsher and stronger sheet and one of higher folding endurance. Undoubtedly, there is more dirt in the samples than would be tolerated by the trade, but this was to be expected, since in this preliminary work the raw material was sieved by hand screens instead of by automatic machines which would sieve more thoroughly.

CONCLUSIONS.

There appears to be little doubt that under the present system of forest use and consumption the present supply can not withstand the demands placed upon it. By the time improved methods of forestry have established an equilibrium between production and consumption, the price of pulp wood may be such that a knowledge of other available raw materials may be imperative.

Semicommercial paper-making tests were conducted, therefore, on hemp hurds, in cooperation with a paper manufacturer. After several trials, under conditions of treatment and manufacture which are regarded as favorable in comparison with those used with pulp wood, paper was produced which received very favorable comment both from investigators and from the trade and which according to official tests would be classed as a No. 1 machine-finish printing paper.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO MATERIALS FOR PAPER MAKING.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Suitability of Longleaf Pine for Paper Pulp. Department Bulletin 72.
Zacaton as a Paper-Making Material. Department Bulletin 309.
Utilization of American Flax Straw in the Paper and Fiber-Board Industry. Department Bulletin 322.
Crop Plants for Paper Making. Bureau of Plant Industry Circular 82.
Pulp and Paper and Other Products from Waste Resinous Woods. Bureau of Chemistry Bulletin 159.
Paper-Making Materials and Their Conservation. Bureau of Chemistry Circular 41.
Paper Birch in the Northeast. Forest Service Circular 163.
Experiments with Jack Pine and Hemlock for Mechanical Pulp. Forest Service.
Forest Products Laboratory Series, unnumbered bulletin. 1912.

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON. D. C.

The Grinding of Spruce for Mechanical Pulp. Forest Service Bulletin 127. Price, 15 cents.
Progress in Saving Forest Waste. Yearbook, 1910. Price, $1.
The Utilization of Crop Plants in Paper Making. Yearbook, 1910. Price, $1.

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LUPINES AS POISONOUS PLANTS.

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PART I.—INTRODUCTION.

SUMMARY OF KNOWLEDGE OF LUPINES AS POISONOUS PLANTS.

EARLY HISTORY AND LATER STUDIES.

The lupines have been known from very ancient times, and are mentioned by many authors, e. g., Theophrastus, Marcus Portius Cato Censorius, and Pliny. The last-named author (ed. 1856, pp. 49–50, 452–453)[1] treats of the lupine at length, especially with reference to its use as a green manure. Several species have been used as cultivated crops in Europe, more especially for the reclamation of sandy soils. It has been used also as a fodder crop, and the seeds ground

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Note.—This paper will be of special interest to the stockmen of the West.

[1] Bibliographic citations in parentheses refer to "Literature cited," p. 43.

into meal have been used both for domestic animals and as food for man. In Germany the land utilized for lupine, according to the latest available statistics, is 346,753.3 hectares; on 200,000 hectares of this amount it is cultivated as a green manure. The poorer people among the Greeks and Romans and the Cynic philosophers made use of lupine meal in bread. The bitter principle was recognized not only as disagreeable, but as injurious, and the seed was especially prepared in order to get rid of this property. Among the Greeks the seeds were cooked until soft, to remove the outer skin, then placed in sacks in shallow places on the seashore to wash out the bitter principle. Afterwards the seeds were dried, ground in a hand mill, and baked into a poor bread. Only the poorest people used this meal unmixed, but others mixed it with other kinds of meal, making a more digestible flour. (Landerer, 1852.) Because the lupines were planted in Maina and there used for food, the people in that region were known as "Lupinophagi." Lupine meal was also used by the ancient Egyptians, and is still used in Andalusia, Corsica, and Piedmont. (Cornevin, 1893, p. 314.) In modern times lupine meal, after a process of "Entbitterung," has been used to some extent as food for animals.

As a medicine, lupine seeds have been used since ancient times. Pliny (ed. 1856, p. 452–453) enumerates 35 different uses. The main uses, however, seem to have been as a cathartic and as a vermifuge. For the latter it was used as an external application as well as internally.

Bellini (1876) reports in detail cases of poisoning in man from using a decoction of lupine as an enema. He states that Averrhoes and Hofman pointed out the poisonous properties of the plants, and that Paullus, 1708, reports a case of poisoning of a boy by an enema. The reference to Averrhoes and Hofman could not be verified, as apparently they only mentioned the plants as a vermifuge. The symptoms mentioned by Bellini are dyspnœa, defective sight, dilated pupils, and stupor. These symptoms, as will be seen later, compare fairly well with those of poisoning by the lupine alkaloids.

Isolated cases of poisoning by lupines were noted as early as 1860, but it was in 1872 and the following years that heavy losses of sheep occurred in northern Germany. While there is evidence that some animals are poisoned by the alkaloids, most of the cases, and practically all of the losses, have been from the use of lupine hay and are caused, as will be seen later, by ictrogen. The occasional poisoning of cattle and horses reported in Europe appears to have been from the use of the seed and is alkaloidal poisoning. Sheep are also poisoned in this way, but the great losses which have stimulated the extensive investigation of the subject have been by ictrogenic poisoning of sheep.

In America the first published report of losses of sheep is by Chesnut (1899, p. 404–405), and this report with the papers of Wilcox (1899), Chesnut and Wilcox (1901, p. 100–110), and Slade (1903), comprise all that has been published up to the present time. Other authors have mentioned the subject, but their material is all taken from the reports of Wilcox, and Chesnut and Wilcox. The first general account of lupine poisoning in America is by Wilcox (1899). A much more extended account is given by Chesnut and Wilcox (1901, p. 100–110), with details of cases and symptoms. Wilcox notes that mature plants are the more poisonous, and Chesnut and Wilcox definitely state that the toxic principle is mainly in the pods and seeds and that lupine hay should be cut after the seeds are shed. Both Wilcox, and Chesnut and Wilcox apparently consider the poisoning of sheep in America as similar to the disease called "lupinosis" in Germany, although Chesnut and Wilcox (1901, p. 109) state that the "chronic form of the disease" has not been recognized in America. Sollmann, in an unpublished report of a laboratory study of American lupines, a report made under the direction of the Bureau of Plant Industry, which will be discussed more fully later, states that he failed to find evidence of the presence of ictrogen and gives details of the symptoms produced by the alkaloidal substances extracted by him. His work was not connected with field investigations, but the results, viewed in the light of present knowledge, clearly indicate the probability that the field cases of poisoning by lupine in America are not cases of "lupinosis" in the sense in which the term is used in Europe, but are the result of alkaloidal poisoning. The field investigations reported in this paper establish without a doubt the fact that, so far as observed, all cases of poisoning of range sheep by lupines must be considered as due to the alkaloids and not to ictrogen. These field investigations are in entire harmony with the preliminary laboratory study by Dr. Sollmann, although carried on in an independent way without reference to the preceding results obtained in the laboratory.

ANIMALS POISONED BY LUPINES.

While the losses of domestic animals have been mainly of sheep, other animals also are poisoned—horses, cattle, goats, swine, and fallow deer—and laboratory experiments on small animals indicate that none are immune to the effects of the toxic substances.

Wilcox (1899) states that in Montana a few horses have been poisoned, and Chesnut and Wilcox (1901 p. 100–110) give specific instances. Poisoning of horses on the range or in pastures is not common, but is known to occur. Dammann (1902) states that cattle are affected by the alkaloid, and cases of the poisoning of cattle on the range have been reported in America, although the cases are not very well authenticated.

LOSSES FROM LUPINES.

The losses from "lupinosis" in Europe have in some years been very great. In 1880, in Pomerania the loss of sheep was 5.89 per cent (Cornevin, 1893, p. 316). It is stated that in some herds in northern Germany the loss was as great as one-half to three-fourths of the total number.

The known losses in America are very heavy. Chesnut and Wilcox (1901, p. 106) tell of one case, among others, in which out of 2,000 sheep trailed over a region covered with a large quantity of lupine 1,000 were sick and 700 died. In another case 1,150 died out of 2,500 (p. 104). Losses of several hundred are not at all uncommon, and occasionally the deaths may be nearly 50 per cent of the whole number. More complete knowledge of the losses has been obtained in Montana than in any other State, because Montana has been under close observation for many years, and it is very possible that this State suffers more than others, but more or less similar conditions are found in other western States in which the mountain regions are used for sheep grazing. It is probable that the lupines rank as a close second to Zygadenus in causing losses of sheep.

DISTRIBUTION OF LUPINES.

While lupines are found in the eastern United States rather sparingly, and are there represented by only three species, in the Western States there is a large number of species, and these frequently grow in large masses, so that sometimes they are cut for hay. They form an important factor in the number of forage plants. Horses seem to be especially fond of them and will sometimes eat the green plants with great greediness.

Of the species of lupines in America, only a few have been used in this investigation. One of these, *Lupinus sericeus*, is illustrated in figure 1. A thorough systematic study of the genus is in progress by the Bureau of Plant Industry, and further work is being prosecuted for future publication, dealing with the characteristics of the different species from the standpoint of chemistry and pharmacology, as well as from the standpoint of field experimentation.

COMMON NAMES OF LUPINES.

The lupines are known under a large number of common names. Among these are sundial, old-maid's bonnets, Quaker's bonnets, Indian beans, wild beans, blue pea, and blue bean. In some sections the name loco is used, but this is generally by those who do not know the true locoes.

ALKALOIDS OF LUPINES.

No investigations of the alkaloids of American lupines have been published, but the European lupines have been the subject of extended study, and the literature, especially of the chemistry of the alkaloids, is very large.

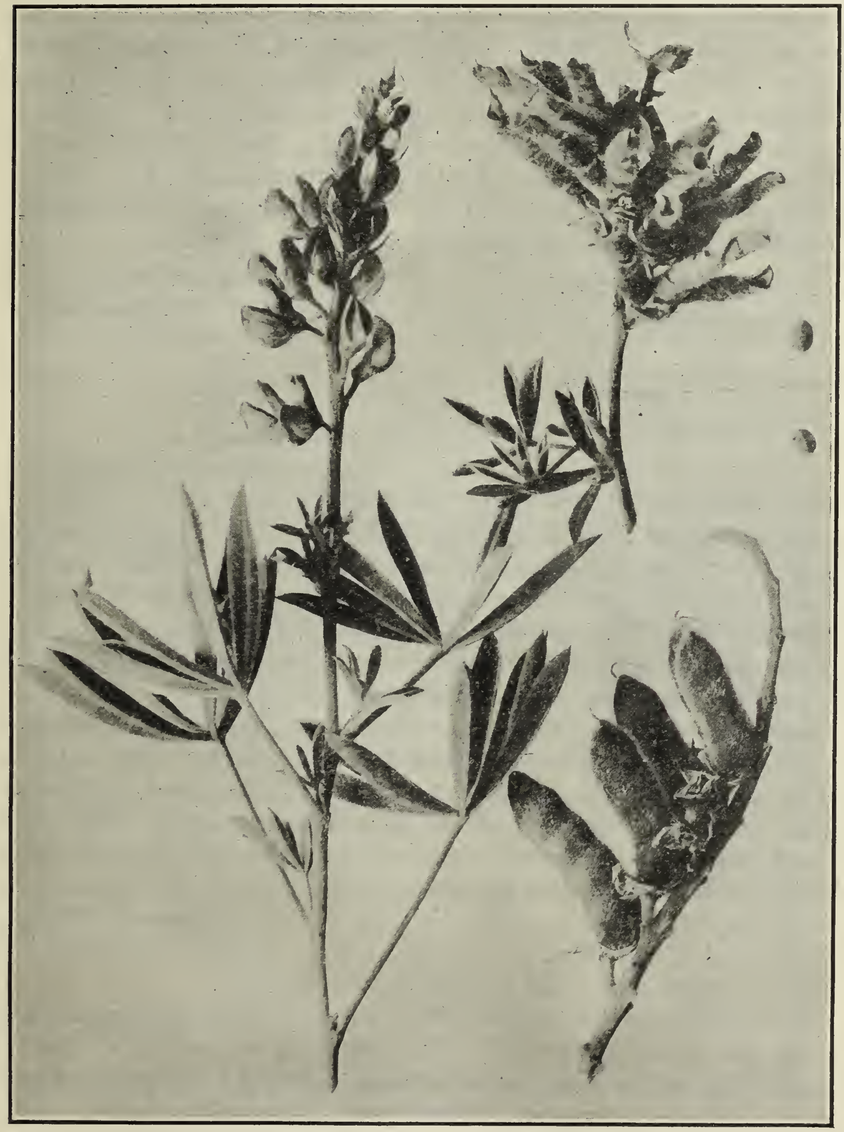

FIG. 1.—Lupine (*Lupinus sericeus*).

Cassola (1834) attempted to isolate the alkaloid of *Lupinus albus*, but probably did not obtain the pure alkaloid. Landerer (1852) obtained a substance that showed a beginning of crystallization, which he called lupinin. Beyer (1871), found an alkaloid in lupine from a study of *Lupinus luteus*. Baumert issued a series of papers from 1881 to 1889. Baumert (1886) summarizes the knowledge to date and announces definitely the presence of two alkaloids in *Lupinus luteus*, lupinin ($C_{21}H_{40}N_2O_2$), and lupinidin ($C_8H_{15}N$). Schmidt (1897), Davis (1897), Callsen (1899), Schmidt (1904), and Bergh (1904) summarize and bring the subject to date with extensive additions to the detailed chemistry of the alkaloids. Schmidt (1897) states the alkaloids as lupinin ($C_{21}H_{40}N_2O_2$), lupinin ($C_8H_{15}N$), "dextrorotatory-lupanin" ($C_{15}H_{24}N_2O$), and inactive lupanin ($C_{30}H_{48}N_4O_2$).

These are found in the lupines examined, as follows:

Lupinus angustifolius	dextrorotatory-lupanin.
Lupinus albus	dextrorotatory-lupanin. inactive lupanin.
Lupinus luteus	lupinin. lupinidin.
Lupinus niger	lupinin. lupinidin.
Lupinus perennis	dextrorotatory-lupanin.

Lupinidin is identical with spartein $C_{15}H_{26}N_2$ (Muenk, 1914, p. 394).

Callsen (1899) gives an extended account of the chemistry of the alkaloids of *Lupinus angustifolius* and *L. perennis*. Willstätter and Fourneau (1902) give experimental evidence that the formula of lupinin is $C_{10}H_{19}ON$. Schmidt (1904) and Bergh (1904) in extended papers discuss further the alkaloids and state that another alkaloid is found in *Lupinus perennis*, oxylupanin ($C_{15}H_{24}N_2O_2$).

Liebscher (1880), Löwenthal (1888), and Raimondi (1891) give details of the pharmacology of the lupine alkaloids. The action of all is practically the same but differs quantitatively. Liebscher states that lupinidin is 10 times as active as lupinin. There is a direct paralysis of the medulla and cord, the respiratory center being first paralyzed, and then the vasomotor. This is accompanied by weakening of the heart. There is a fall in blood pressure, a slowing of the pulse, and dilation of the pupils. Death is produced by asphyxia, with which are associated convulsions.

There is no curare action. The dose required to produce any symptoms is ordinarily fatal. The alkaloids are less poisonous for mammals than for cold-blooded animals. Small repeated doses produce no effect, nor do they establish a condition of tolerance.

ICTROGEN.

Early in the investigation of the poisoning of domestic animals in northern Europe by lupines, causing the disease which came to be known as "lupinosis," it was observed that these were not cases of poisoning by the recognized alkaloids of the lupines. Lupinosis has a definite line of symptoms distinctly different from those produced by the alkaloids, especially characteristic being a hepatitis, which produces a jaundice exhibited in the conjunctiva and visible mucous membranes of the living animal. Kühn (1880), Roloff, (1883), Arnold and Lemke (1881), as well as others, found that the intoxication known as lupinosis could not be produced by alcoholic extracts, but was produced by the marc of the seeds; if the poisoning were alkaloidal, the reverse would be the case. Dammann (1902, p. 343) states that the plant often becomes more toxic on keeping. Moreover, while the alkaloids are always present the ingredient producing lupinosis is inconstant. The plants raised on some fields always produce poisoning, while on others they are harmless (Raimondi, 1891). It was found (Dammann, 1902, p. 342) that the substance producing the disease is insoluble in alcohol, ether, glycerine, and fatty oils, and is soluble with difficulty in water. It is not readily destroyed by dry heat, but steam under pressure makes it harmless. This hypothetical substance was called ictrogen by Kühn (1880) and lupinotoxin by Arnold and Schneidemühl (1883). It has only been recognized by its physiological action.

Ictrogen is not considered to be a product of the metabolism of the lupine, but to be the result of the growth of microorganisms upon the plants. This explanation is not based, however, upon any experimental evidence, but is reached by a process of elimination of other possible theories. This is the theory advanced by Dammann (1902, p. 341–343). Other theories of the cause of lupinosis have been advanced. For example, Zürn (1879) propounded a theory that the disease is produced by microorganisms in or on the lupine leaves; in other words, that lupines do not cause the disease, but simply serve as a carrier. This theory has not been taken very seriously by others, while the theory that the disease is produced by ictrogen and that this substance is produced through the action of some unknown microorganisms upon the lupines is quite generally accepted as the most probable explanation.

PART II.—EXPERIMENTAL WORK.

PHARMACOLOGICAL INVESTIGATION BY SOLLMANN.

SCOPE OF THE WORK.

A series of experiments upon Montana lupines, identified as *Lupinus sericeus*, *L. leucophyllus*, and *L. cyaneus*, was conducted by Dr. Torald Sollmann, under the general direction of V. K. Chesnut, then in charge of the work on poisonous plants in the United States Department of Agriculture, and following is a report of the results.

Eighteen animals, rabbits and guinea pigs, were fed upon pods and seeds with no results, none of them eating enough to produce toxic effects.

Extractions were made of the seeds and pods, and impure alkaloids were obtained. The experience in this work leads to the suggestion of the following method of extraction:

Moisten the powdered drug with alcohol containing 1 per cent of HCl; pack in percolator; macerate with alcohol; percolate with alcohol until the percolate gives only small turbidity with Mayer's reagent. Mix the percolate with sand and evaporate the alcohol. Treat the residue repeatedly with warm water, until it gives off only a slight reaction with Mayer's reagent. To the united filtrate add Mayer's reagent to complete precipitation. Wash the precipitate, suspend it in a little water, and decompose with H_2S; filter.

Evaporate the filtrate to a small volume, add an excess of $Ca(OH)_2$, filter, exhaust the precipitate and filtrate separately with ether, as quickly as possible, neglecting the last traces. Evaporate the ether. Treat the residue with absolute alcohol acidulated with H_2SO_4. Let stand 24 hours. The precipitate will contain the lupinidin, the filtrate the other lupine alkaloids. These will require further purification.

CHARACTERS OF THE ALKALOIDS.

Physical characters.—The physical effects of the aklaloids make it likely that they are similar to those occurring in the European species. Several of these characters were observed in the course of the isolation of the alkaloids.

The (impure) alkaloids were obtained as brown oily liquids of a strongly alkaline reaction and a strongly bitter taste. They were easily soluble in water and in alkalies. They were slightly soluble in petroleum ether. No crystals were obtained. During their separation a strong odor resembling conin, characteristic of lupinidin, was perceptible, especially when strong soda was added. The isolated alkaloids were almost odorless, but again developed the odor very strongly when 10 per cent soda was added.

Chemical characters.—Strongly heated, they boiled and evolved dense, white fumes. Strong sulphuric acid, cold or heated, alone or with formaldehyde or bichromate, gave only browning. Strong nitric acid also gave no characteristic reactions.

Precipitation reactions.—The alcoholic solution gave partial precipitation with sulphuric acid. The dilute neutral aqueous solutions of the chlorid or sulphate behaved as follows:

NaOH (1 per cent): Slight precipitate.

NaOH (strong): Precipitate, partly soluble n excess of the soda.

$(NH_4)OH$: No precipitate.

Na_2CO_3: No precipitate.

Mercuric chlorid: Amorphous precipitate, easily soluble in excess of HCl. The precipitate was incomplete, giving further precipitate with Mayer's reagent, and also the lupinidin test with alcoholic sulphuric acid.

Picric acid: Fair amorphous precipitate.

Tannin: Precipitate, soluble in excess.

Iodin in KI: Good amorphous precipitate.

Pot. ferrocyanid: No precipitate.

Pot. bichromate: No precipitate.

Nature of the alkaloids.—The alkaloids were not obtained sufficiently pure to make definite characterizations possible. Their close agreement with those obtained from the European species in physiological action and fatal dose make it very probable that they are closely related, if not identical. Lupinidin was fairly well identified by the conin odor, by the insolubility of the double chlorid formed with mercury, and by the insolubility of the acid sulphate in absolute alcohol. The precipitation by these reagents was not complete, so that there must be other alkaloids present, presumably lupinin and lupanin. This portion of the work needs further elaboration.

The yield of crude alkaloids in the extraction was as follows:

Specimen IV: *Lupinus sericeus*, parasitized pods, 0.02 per cent from alkaline extract; 0.133 per cent from watery extract.

Specimen V: *Lupinus cyaneus*, seed, 2.462 per cent.

Gerhard found from 0.5 to 1.2 per cent in the European lupines.

TOXICITY OF THE EXTRACTS.

The various extracts, prepared as described, were administered to rabbits and guinea pigs, by mouth, stomach tube, and hypodermically. The symptoms were practically identical, and will be described later. It was found:

(*a*) That the toxic principles must be alkaloidal rather than ictrogenic.

(*b*) That the fatal dose of the drug (as extracts) to rabbits by stomach, in the case of the seeds of *Lupinus sericeus* and *L. leucophyllus*, was between 30 and 50 grams per kilogram, with the seeds of *L. cyaneus* between 70 and 100 grams per kilogram, and with empty pods of *L. sericeus* and *L. cyaneus* over 100 grams per kilogram.

(*c*) That the fatal dose of the crude alkaloids (in the purest form in which they were used, from Specimen V) lies, for rabbits, gastric administration, between 1.2 and 2.4 grams per kilogram; for rabbits, hypodermic administration, between 0.123 and 0.246 grams per kilogram (agrees with Löwenthal's (1888) figures for lupinidin and lupanin, viz, 0.2 and 0.4); for guinea pigs, hypodermic administration, between 0.052 and 0.1 gram per kilogram.

(*d*) That the alkaloids are five to ten times as toxic for rabbits when given hypodermically as when given by the stomach tube.

(*e*) That guinea pigs are about twice as susceptible to the poison, when given hypodermically, as rabbits are.

(*f*) That repeated administration of the poison to animals did not increase their susceptibility, as is shown by the fact that rather prolonged feeding was not fatal, and that no tolerance is produced in this manner, as is shown by rabbits 77 and 78 A. The animals in either case, after having been injected repeatedly, died from the last dose, although these doses were not very greatly above the fatal limit.

SYMPTOMS OF LUPINE POISONING.

It will be useful to describe the typical course, which occurs with only minor variations when any of the extracts are administered. The symptoms set in with a general depression. The animal is very quiet, sits flat with ears laid back; the respiration is rapid, labored, and irregular. The temperature is not altered in a constant manner. After a time it is noted that the animal, while apathetic if left alone, is quite excitable when disturbed. The reflexes are heightened. The movements are brusque and exaggerated. The depression gradually deepens; the animal partly loses control of its hind legs, so that these tend to drag. Often the animal lies on its belly, the head on the floor and legs spread out. It is still able to walk. It soon loses this ability and sits or lies still. When disturbed, it reacts with shivering, and becomes more and more convulsive. Stimulation now produces more or less violent spasms, the first spasm being strongly tetanic. The animal may assume the strychnin position, with legs stretched out, and back arched in; or it may rise on its feet, the back arched upward. The spasm soon becomes clonic and incoordinated, the animal pawing the air in an aimless manner. This is followed by relaxation, and the animal remains quiet unless disturbed, which disturbance would cause another spasm. After a time the convulsions occur spontaneously. In milder cases there may be no general convulsions, but twitching of isolated muscles—of the face, ears, neck, back, and extremities. The head may swing in a rhythmical pendulum movement. The respiration during this convulsive paralytic condition is slow, shallow, and irregular. The pupils are variable, but need not be dilated (which speaks against the view that they are asphyxial; the mucous membranes are also a bright pink). Many animals urinate copiously. The animals may remain on the abdomen or recover a sitting posture for some time after the onset of the convulsions, but after a time they fall on the side. The respiration becomes gasping. Asphyxial convulsions set n, and the respiration stops from half a minute to 1 minute before the heart.

The depressant and convulsive symptoms agree with those described by Löwenthal (1888), Gemma (1882), and Raimondi (1891) for European lupine alkaloids.

It is not possible to make any general statement as to the time required for the development of the different symptoms, since this is extremely variable. It is remarkable, however, that a considerable time may elapse before any pronounced symptoms appear, and this even when the solutions are administered under the skin. It is to be noted that doses which are little below fatal produce only very slight symptoms.

Recovery may occur from any stage and is usually so complete that the animal gains on its original weight. The intoxication leaves no post-mortem lesions, gross or microscopical.

OPERATIVE EXPERIMENTS WITH LUPINE ALKALOIDS.

The effects on blood pressure, respiration, etc., were studied on five dogs, anæsthetized with morphin and ether, and arranged for tracings. The alkaloidal extract of Specimen V (seeds of *Lupinus* *cyaneus*) was injected into the femoral vein, in progressively increasing doses. The dose is calculated as grams of drug (not of alkaloid) per kilogram of body weight. Arranged by doses, the effects were briefly as follows:

SMALL DOSES OF 0.1 TO 0.4 GRAM PER KG.

Respiration: First quicker and deeper; then somewhat slowed; irregular, and shallow.

Carotid blood pressure: Rise, fall, rise, normal.

Heart: Rate somewhat quickened; strength somewhat diminished.

TOXIC DOSES OF 0.5 TO 0.75 GRAM PER KG.

Respiration: First quickened and deeper; then somewhat slowed, irregular, and shallow; may stop.

Carotid blood pressure: Rise, then great fall; effect of sciatic stimulation lessened.

Heart: Rate first slowed, then quickened; when vagi were cut, slowed; strength, weakened.

VERY LARGE DOSES OF 0.9 TO 6.25 GRAMS PER KG.

Respiration: For a few moments deeper; then very shallow and stops.

Carotid blood pressure: First slight rise, then great fall.

Heart: Rate first slowed, then quickened, then stopped; strength weakened.

Convulsions may occur from 1 gram up.

DISCUSSION OF EFFECTS.

Respiration.—The respiration shows a short stimulation (increase of rate and depth), followed by depression (slowed, irregular, shallow); with the larger doses it stops before the heart. The action is probably on the centers, for it occurs after section of the vagi, and when stoppage has occurred it can not be revived by asphyxia, slapping, or stimulation of the sciatic, or injection of saline. No recovery occurs from even a just fatal dose after an hour of artificial respiration. The respiratory center is the first vital center to give out completely.

Blood pressure.—This shows a short, moderate rise, followed by a more lasting fall, which is quite marked with the larger doses, even those which are not fatal. Although the changes often coincide with respiratory changes, the two are not interdependent, for they may occur independently, and blood pressure changes occur even during artificial respiration and are not influenced by the latter. Whether the changes were central or peripheral was not investigated directly; but, from the fact that when vasomotor paralysis exists stimulation of the sciatic is sometimes effective and sometimes ineffective when asphyxia is effective, it is rendered very probable that the action is central. The vasomotor paralysis may precede, coincide, or follow that of respiration. It may be partial or so nearly complete that the pressure sinks to some 20 millimeters with a good heart action.

The heart rate.—With toxic doses there is first slowing, then quickening; with minimal and maximal doses, there is usually quickening only. The slowing and secondary quickening occur equally well when the vagi are divided; they are therefore at least partly peripheral. They are not always accompanied by changes in the strength of the heart, hence they are probably not muscular. Further, when the heart is quickened by large doses, electric stimulation of the vagus has but little effect. The drug may therefore be said first to stimulate and then depress the vagus end mechanism. It may have a similar action on the vagus center.

Strength of the heart.—This is affected only by rather large doses, but it is then always depressed. Experiment 87 shows that the life may be kept up with a complete vasomotor paralysis, if the heart beats well. This tends to show that the stoppage of the heart, which forms the final cause of death, must be due to paralysis of its muscles. This is confirmed by the fact that it can not be revived by injection of normal saline.

Convulsions.—Convulsions were observed in but two of the five cases. This may be due to the anæsthetic or to the difficulty of securing proper dosage. When observed, however, they preceded respiratory distress and were not connected with any change in blood pressure, so that it seems that they are produced by a direct central action.

Skeletal muscle.—The existence of convulsions in the last stages, as well as the result of stimulation of peripheral and of the sciatic, show that muscle and nerve are not paralyzed.

Cause of death.—The following vital functions are eventually paralyzed by the lupine: Respiratory center; vasomotor center; cardiac muscle; the last named being the last to become paralyzed and being the final cause of death.

SUMMARY.

The results of the investigations are in many respects incomplete and emphasize the need of a more exhaustive chemical and pharmacological study of the American lupines. They have shown, however, that these lupines contain alkaloids which are toxic or fatal if a sufficient quantity of the plant is consumed, but which are harmless if the consumption is below a certain limit. Up to this point the lupines may be a useful food if due precautions are observed that the limits are not surpassed. These alkaloids could also be largely removed by leaching with water. The ictrogen, which is especially feared in Europe, was not found in any of the American samples. It would be of great importance to determine whether this ictrogen is uniformly absent, for if it is not, much more stringent precautions would be necessary.

CONCLUSIONS.

1. Feeding with the lupines does not produce any symptoms in rabbits and guinea pigs, as a sufficient quantity is not taken in this manner.

2. The injection of extracts, by stomach or skin, is fatal if sufficiently large doses are used.

3. No ictrogen was found in any of the six specimens.

4. The toxic constituents are alkaloidal and seem to agree with those of the European species.

5. These alkaloids produce a stimulation and then a paralysis of the following structures: The respiratory and vasomotor centers, some convulsive centers, the vagus end mechanism, and perhaps the vagus center. Large doses given intravenously paralyze the heart muscle. The convulsions do not appear to be purely asphyxial.

6. Pronounced symptoms are seen only when almost fatal doses are given; smaller amounts do not produce any conspicuous effects. When death does not occur acutely, there are no late effects. Repeated administration has no influence on the action.

7. The cause of death is paralysis of respiration. Death occurs, with hypodermic administration, in 12 minutes to 2½ hours; when given by stomach, in 10 minutes to 3¼ hours. The symptoms set in only shortly before death.

8. The fatal doses for rabbits by the stomach, figured for the original drugs, are as follows: For the seed of *Lupinus sericeus* and *L. leucophyllus*, between 30 and 50 grams per kg.; for the seed of *L. cyaneus*, between 70 and 100 grams per kg.; for the hulls of *L. cyaneus*, and *L. sericeus*, over 100 grams per kg.

9. The fatal dose of the crude alkaloid for rabbits, gastric administration, lies between 1.2 and 2.4 grams per kg.; for rabbits, hypodermic administration, between 0.123 and 0.246 gram per kg.; for guinea pigs, hypodermic administration, between 0.062 and 0.1 gram per kg.; for dogs, intravenous administration, about 0.012 gram per kg.

10. The fatal dose for rabbits is between 5 and 10 times as large when the alkaloids are given by the stomach as when given intravenously. Guinea pigs are more susceptible to the alkaloids than rabbits when the solutions are administered hypodermically.

11. In the treatment of the poisoning, artificial respiration was found useless. Good results were obtained with potassium permanganate, diuretin, and tea.

FIELD EXPERIMENTS WITH LUPINES.

Field experiments with domestic animals have been carried on for six years—in 1909, 1910, and 1911 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont. Two species, *Lupinus comatus* and *L. myrianthus*, were used at the Mount Carbon station. At Greycliff most of the work was done with two local species, *L. leucopsis* and *L. argenteus*, but two feedings were made with *L. leucophyllus* collected in Idaho in the Caribou National Forest. Not only were different species used, but feedings were made of different parts of the plants and also with the plants at different stages of growth.

TABLE 1.—*Summary of feeding experiments with Lupinus in 1909, 1910, and 1911 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*

Animals designated by an asterisk (*) preceding the serial number were given dry material, but the figures for dose are reduced to green weight, except in cases where "dry" is noted.]

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used for stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
A.—Horses given *L. myrianthus:*	*Pounds.*	*Pounds.*						*Per 1,000 pounds.*	
No. 78	600	26.5	1909. Sept. 22 and 23	Leaves, stems, flowers, and fruit	Sick	None	Recovery	44.2	Camp.
No. 72	700	54	Sept. 22 to 26	do	Death	do	Death	77.2	Do.
No. 78	600	23.25	Sept. 25 and 26	do	Sick	do	Recovery	38.7	Do.
No. 78	750	33	1910. Sept. 10 to 13	Leaves, stems, and fruit	do	Magnesium sulphate.	do	44	Castleton.
No. 78	750	81	Sept. 14 to 17	do	Not sick	None		108	Do.
No. 78	700	125.5	1911. July 27 to Aug. 1	Leaves, stems, and flowers	Sick	Magnesium sulphate.	do	179.3	Do.
No. 124	1,000	158	Aug. 3 to 11	do	Not sick	None		158	Baldwin.
No. 124	1,000	234.5	Aug. 17 to 26	Seed heads	do	do		234.5	Do.
B.—Horses given *L. comatus:*									
No. 78	700	172.5	June 18 to 26	Leaves, stems, flowers, and fruit	do	do		246.4	Castleton.
No. 78	700	292	July 6 to 15	do	do	do		417.1	Do.
C.—Cattle given *L. myrianthus:*									
No. 108	430	30.5	1909. Sept. 26 to 29	Leaves, stems, and fruit	do	do		71.43	
No. 620	500	45	1910. Sept. 14 to 17	do	do	do		90	Do.
D.—Sheep given *L. comatus:*								*Per 100 pounds.*	
No. 124	90	60	June 5 to 23	Leaves, stems, and flowers	do	do		66.7	Gray's.
No. 120	83	19.75	June 23 to July 5	do	do	do		23.8	Webber Park and camp.
No. 122	96	33.75	do	do	do	do		35.2	Do.
No. 101	80 to 77	95	July 6 to 20	Leaves, stems, and fruit	do	do		119	Camp.
No. 102	86 to 85	109.5	do	do	do	do		128	Do.
No. 113	113 to 108	118.5	July 30 to Aug. 12	do	do	do		104.8	Castleton.

E.—Sheep given *L. myrianthus:*									
No. 116	100 to 90	81	July 30 to Aug. 11.	Leaves, stems, and flowers	do	do		81	Do.
No. 123	99 to 88	23.5	Aug. 13 to 24	Fruit and flowers	do	do		23	Do.
No. 105	100 to 90	55.5	Aug. 25 to Sept. 7.	Fruit	do	do		55.5	Do.
No. 119	112 to 97	19.5	Sept. 6 to 10	do	do	do		17.4	Do.
F.—Sheep given *L. comatus:*			1911.						
No. 138	121	41	June 17 to 25	Leaves, stems, and flowers	do	do		33.9	Do.
No. 139	±110	27	do	do	do	do		24.5	Do.
No. 144	103	75	June 28 to July 6	Leaves, stems, flowers, and fruit	do	do		72.8	Do.
No. 148	130	72.5	do	do	do	do		55.8	Do.
No. 146	118	101	July 8 to 19	do	do	do		85.6	Do.
No. 153	111	76	do	Leaves, stems, and fruit	do	do		68.5	Do.
No. 143	121 to 120	60.5	July 29 to Aug. 9	Seed heads	do	do		50	Do.
No. 137	153 to 146	49.76	Aug. 10 to 17	do	do	do		32.5	Do.
G.—Sheep given *L. myrianthus:*									
No. 140	94	100	July 8 to 19	Leaves, stems, and flowers	do	do		106.4	Do.
No. 150	107	15	July 25 to 28	Leaves, stems, flowers, and fruit	do	do		14	Do.
No. 156	113	7	do	do	do	do		6.2	Do.
No. 147	120 to 114	88.25	July 30 to Aug. 14.	Seed heads	do	do		73.5	Castleton and Baldwin.
No. 146	121 to 115	110.5	Aug. 5 to 23	Leaves, stems, and flowers	do	do		91.3	Do.
No. 145	125 to 116	69	Aug. 19 to 30	do	do	do		55.2	Baldwin.
H.—Sheep given *L. leucopsis:*			1912.						
No. 170	79 to 65	15.75	July 13 to 27	Leaves, stems, and fruit	do	do		19.94	Greycliff station.
No. 167	71 to 62	10.5	July 16 to 27	do	do	do		14.8	Do.
No. 164	92½ to 81½	82.5	July 22 to Sept. 5	do	do	do		89.19	Do.
No. 177	50	1.5	July 30 to Aug. 2	Fruit	do	do		3	Do.
No. 180	57	1.24	do	do	do	do		2.17	Do.
No. 171	78 to 72	18.5	do	Leaves and stems	do	do		23.72	Do.
No. 176	72 to 64	13	do	do	do	do		18.05	Do.
No. 172	79½	2	Aug. 5 to 7	Fruit	do	do		2.515	Do.
No. 173	71½	1.3	do	Fruit (in corn chop)	do	do		1.82	Do.
No. 163	66½ to 52	8.5	Aug. 8 to 13	Leaves and stems	do	do		12.78	Do.
No. 175	92	1.32	Aug. 12	Fruit (drench)	do	do		1.435	Do.
No. 168	63	2.645	Aug. 14	do	do	do		4.198	Do.
No. 162	99 to 89	16	Aug. 16 to 21	Leaves, stems, and fruit	do	do		16	Do.
No. 172	78½ to 67½	19	Aug. 24 to Sept. 2	do	do	do		24.2	Do.
No. 180	59	.502	Sept. 15	Seed, unground (in oats and chop)	Death	do	Death	.85	Do.
			1913.						
No. 209	78½ to 72	.441	Aug. 15	Seed, unground (in grain)	Sick	do	Recovery	.561	Do.
No. 210	82 to 74	.220	do	Seed, ground (in bran)	Very sick	do	do	.268	Do.
No. 201	71	.385	Aug. 17	do	Death	Tannic acid (drench); gin.	Death	.542	Do.
No. 184	62½	.441	do	Seed, unground (in grain)	do	None	do	.705	Do.
No. 195	82½ to 75	.135	Aug. 19	Seed, ground (in bran)	Not sick	do		.164	Do.

TABLE 1.—*Summary of feeding experiments with Lupinus in 1909, 1910, and 1911 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used for stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
	Pounds.	*Pounds.*						*Per 100 pounds.*	
No. 198	73½ to 71	0.161	Aug. 19	Seed, ground (in bran)	Not sick	None		0.219	Greycliff station.
No. 203	108 to 95	.364	do	do	do	do		.337	Do.
No. 190	72 to 67	.317	Aug. 22	do	do	do		.440	Do.
No. 208	84 to 86	.463	do	Seed, unground (in grain)	do	do		.515	Do.
No. 211	86 to 76	.214	Aug. 23 and 24	Seed, ground (in bran)	do	do		.249	Do.
No. 196	75 to 68½	.319	Aug. 25 and 26	do	do	do		.425	Do.
No. 185	64	.282	Aug. 31	do	Death	do	Death	.441	Do.
No. 202	73 to 69	.282	do	do	Not sick	do		.386	Do.
No. 212	83½ to 80	.205	Sept. 2	do	Sick	do	Recovery	.245	Do.
No. 203	110½ to 100	.485	Sept. 6	do	do	do	do	.439	Do.
No. 196	75½ to 70	.273	Sept. 13	do	Not sick	do		.361	Do.
I.—Sheep given *L. argenteus:*									
No. 215	75½ to 66	.004	Sept. 3 and 4	do	do	do		.006	Do.
No. 207	77 to 69	.326	Sept. 5	do	do	do		.423	Do.
No. 190	71½ to 70	.245	Sept. 13	do	do	do		.332	Do.
No. 210	79½ to 73	.350	Sept. 16 and 17	do	do	do		.440	Do.
J.—Sheep given *L. leucophyllus:*									
No. 193	76½ to 75	.337	Sept. 15	Seed heads	do	do		.440	Caribou National Forest, Idaho.
No. 202	72½	.638	Sept. 18 and 19	Seed, ground (in bran)	do	do		.880	Do.
K.—Sheep given *L. leucopsis:*			1914.						
No. 259	116 to 107¼	.384	June 8	Flower heads, young (drench)	do	do		.331	Station.
No. 262	84 to 80	.556	do	Leaves (drench)	do	do		.662	Do.
No. 277	98½	.869	June 10	do	do	do		.882	Do.
No. 280	101	.445	do	Flower heads (drench)	do	do		.441	Do.
No. 292	88 to 79	.776	July 16	Fruit, fully developed (forced feeding)	Not sick (depressed).	do		.882	Do.
No. 291	84½ to 89½	.373	July 17	do	Not sick	do		.441	Do.
No. 277	90 to 87	1.190	July 18	do	do	do		1.322	Do.
No. 278	83½	1.473	July 19	do	Death	Chloral and atropin.	Death	1.764	Do.
No. 238	83	1.281	July 20	do	do	Caffein	do	1.543	Do.

No. 269	96½ to 95	1.383	July 23	do	Not sick	Tannic acid (drench), magnesium sulphate.		1.433	Do.
No. 240	87½ to 85	1.350	July 24	do	Symptoms	Tannic acid (drench).	Recovery.	1.543	Do.
No. 297	90½ to 89½	1.297	do	do	Not sick	None		1.433	Do.
No. 256	81½	1.437	July 25	do	Death	Tannic acid (drench).	Death	1.763	Do.
No. 255	96 to 92	.992	July 28 to 29	Seed heads, fully developed (forced feeding).	Not sick	None		1.033	Do.
No. 266	88½ to 84	1.244	July 29	Pods with seed removed (forced feeding).	do	do		1.406	Do.
No. 232			July 31	Herded on lupine patch	do	do			Do.
No. 233			do	do	do	do			Do.
No. 235			do	do	do	do			Do.
No. 237			do	do	do	do			Do.
No. 240			do	do	do	do			Do.
No. 241			do	do	Death	Atropin	Death		Do.
No. 243			do	do	Not sick	None			Do.
No. 244			do	do	do	do			Do.
No. 246			do	do	do	do			Do.
No. 247			do	do	do	do			Do.
No. 250			do	do	do	do			Do.
No. 253			do	do	do	do			Do.
No. 255			do	do	do	do			Do.
No. 259			do	do	do	do			Do.
No. 260			do	do	do	do			Do.
No. 263			do	do	do	do			Do.
No. 264			do	do	do	do			Do.
No. 265			do	do	do	do			Do.
No. 267			do	do	do	do			Do.
No. 268			do	do	do	do			Do.
No. 269			do	do	do	do			Do.
No. 271			do	do	do	do			Do.
No. 272			do	do	do	do			Do.
No. 277			do	do	do	do			Do.
No. 280			do	do	do	do			Do.
No. 288			do	do	do	do			Do.
No. 290			do	do	do	do			Do.
No. 291			do	do	do	do			Do.
No. 292			do	do	do	do			Do.
No. 293			do	do	do	do			Do.
No. 294			do	do	do	do			Do.
No. 295			do	do	do	do			Do.
No. 296			do	do	do	do			Do.
No. 297			do	do	do	do			Do.
*No. 232 (dry)	74 to 73	.326	Aug. 3	Ripe pods that had shed seed (forced feeding).	do	do		.441	Do.
*No. 250 (dry)	80 to 85¼	.441	Aug. 4	do	do	do		.517	Do.

TABLE 1.—*Summary of feeding experiments with Lupinus in 1909, 1910, and 1911 at Mount Carbon, Colo., and in 1912, 1913, and 1914 at Greycliff, Mont.*—Continued.

Animal.		Weight of plant used.	Date of experiment.	Part of plant used (fed unless otherwise stated).	Severity of illness.	Remedy.	Result.	Pounds used for stated weight of animal.	Location from which plant used was obtained.
Designation.	Weight.								
	Pounds.	*Pounds.*						*Per 100 pounds.*	
*No. 253	62½	1.722	Aug. 6	Pods with seed removed (forced feeding).	Death	Bled, whisky	Death	2.755	Station.
*No. 247 (dry)	109 to 103½	.721	Aug. 8	Ripe pods that had shed seed (forced feeding).	do	None		.661	Do.
No. 295	92 to 88	2.028	Aug. 10	Leaves (forced feeding)	do	do		2.204	Do.
*No. 280 (dry)	84 to 81	1.648	Aug. 11	Ripe pods that had shed seed (forced feeding).	do	do		.771	Do.
*No. 235 (dry)	82 to 76½	1.085	Aug. 14	do	do	do		1.323	Do.
No. 231	90	.298	Aug. 18	Seed (forced feeding)	Sick	do	Recovery	.331	Do.
No. 243	81	1.058	do	Leaves (forced feeding)	Death	do	Death	1.306	Do.
No. 274	28 to 26	.062	do	Seed (in bran)	Not sick	do		.221	Do.
No. 251	79 to 77	1.301	Aug. 19	Leaves (forced feeding)	do	do		1.647	Do.
No. 266	76	2.392	Aug. 20	do	Enteritis?	do		3.147	Do.
No. 250	97 to 91½	2.138	Aug. 24	do	Not sick	do		2.204	Do.
No. 274	27½ to 27½	.053	do	Seed (in bran)	do	do		.193	Do.
No. 251	80 to 75½	.353	Aug. 27	Seed (forced feeding)	do	do		.441	Do.
No. 268	83	.457	Aug. 28	do	Death	do	Death	.551	Do.
*No. 301 (dry)	81	1.653	do	Ripe pods that had shed most of seed (forced feeding).	do	Magnesium sulphate and caffein.	do	2.041	Do.
*No. 231	84 to 80	1.296	Aug. 29	Fruit, fully developed (forced feeding).	Not sick	None		1.543	Do.
No. 297	84 to 78	.463	do	Seed (forced feeding)	do	Sodium bicarbonate (repeated doses).		.551	Do.
*No. 235	92½ to 80	1.426	Aug. 31	Fruit, fully developed (forced feeding).	do	None		1.541	Do.
*No. 251	79½ to 74	1.400	Sept. 2	do	Not sick? (Possible indigestion.)	do		1.761	Do.
No. 254	90½ to 85½	.499	do	Seed (forced feeding)	Not sick	Sodium bicarbonate (repeated doses).		.551	Do.
*No. 280	84 to 78	1.597	Sept. 4	Fruit, fully developed (forced feeding).	do	None		1, 901	Do.

No. 296	80 to 71	.529	....do	Seed (forced feeding)	...do	Sodium bicarbonate (repeated doses).		.661	Do.
No. 269	95	.733	Sept. 5	.....do	Death	Sodium bicarbonate (repeated doses) and atropin.	Death	.772	Do.
No. 290	88 to 88	4.299	Sept. 7	Leaves (forced feeding)	Not sick	None		4.885	Do.
No. 306	83½ to 78	3.666	Sept. 9	.....do	...do	.....do		4.410	Do.
No. 245		(1)	Sept. 10	Leaves and stems	...do	.....do			Do.
L.—Sheep given *L. argenteus:*									
No. 233	117 to 106	2.579	Aug. 25	Leaves, stems, and a few flowers and seed (forced feeding).	Symptoms?	.....do		2.204	Do.
No. 263	98 to 90	3.241	Aug. 27	Leaves (forced feeding)	Not sick	.....do		3.307	Do.
No. 307	92 to 89½	4.049	Sept. 10	.....do	...do	.....do		4.792	Do.

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[1] Ate a little.

Inasmuch as nearly all the recorded losses are of sheep, most of the work was done with these animals, there being, all told, 141 experimental cases. Two head of cattle were fed, and there were 10 experiments with horses. Table 1 contains a summarized statement of the field experimental work.

EXPERIMENTS WITH CATTLE.

Two head of cattle, Nos. 108 and 620, were fed with lupine, but in neither case was there any result. This should not be interpreted, however, as proving that cattle can not be poisoned by lupine; accounts have reached the Department of Agriculture of the poisoning of cattle in the field under circumstances which make it seem very probable that lupine was the cause. However, it does not seem probable that the lupines cause any serious loss of cattle.

EXPERIMENTS WITH HORSES.

There were 10 experiments of feeding lupine to horses, 8 with *Lupinus myrianthus* and 2 with *L. comatus.* Horse No. 72, between September 22 and 26, 1909, ate, per 1,000 pounds of its weight, 77.2 pounds of lupine, including leaves, stems, flowers, and fruit. The animal died, the marked symptoms being general depression and dullness, abdominal pain, twitching of the surface muscles, and high stepping as he walked about. The animal was very much constipated and in the autopsy there was clear evidence of intestinal impaction. At the time, because of the negative results obtained, it was thought probable that the intestinal impaction was the cause of death, but a review of the case, after more complete knowledge of lupine poisoning, made it appear quite certain that this horse was a victim of lupine intoxication.

The two feeding experiments with horse No. 124 were negative. With horse No. 78 there were five feeding experiments with *Lupinus myrianthus*—two in 1909, two in 1910, and one in 1911. In 1911 there were also two experiments with this horse of feeding *L. comatus.* In four of the experiments with horse No. 78 there were distinct symptoms of illness, consisting of contractions of the surface muscles, intestinal disturbance, indicated in the main by constipation but showing diarrhea in one case, dullness and depression, with a tendency to lift the fore feet unusually high when stepping about.

The experiments with horses were sufficient to establish the fact that these animals may be poisoned by the lupines. No deductions, however, can be drawn as to the toxic dose, since the periods during which the feedings were continued were extremely variable. To establish definitely the dosage for horses would require a large number of carefully conducted experiments comparable with those on sheep, and for such experiments there has been as yet no opportunity.

EXPERIMENTS WITH SHEEP.

In the experimental work with sheep the attempt was made to have the animals, if possible, eat the plant. In experiments with seeds it was found that the extremely bitter taste led the sheep to avoid them, but when they were ground up and mixed with bran the material was eaten quite readily. When it was found difficult, in the case of corral animals, to get them to eat enough to produce any effect, drenching and forced feeding were used. In drenching, the sheep was placed on its haunches and the drench, which consisted of the plant material finely ground and suspended in water, was given by a bottle. For the forced feeding the material was ground and given by means of a veterinarian's balling gun. The plant material fed in this manner was placed a little at a time in the back part of the sheep's mouth. As soon as this was swallowed more was given, and the process continued until the desired quantity had been given to the animal.

TYPICAL CASE OF SHEEP NO. 184.

Sheep No. 184, a 2-year-old ewe weighing 62.5 pounds, was taken into the corrals on August 16, 1913, for feeding. On August 17, at 8.45 p. m., she was given 200 grams of unground seed of *Lupinus leucopsis*, mixed with oats, corn, and wheat, which was equivalent to 0.705 pound per 100 pounds of animal. During the day this was all eaten.

On August 18, at 6.55 a. m., the sheep was found lying partly on one side with her head on the ground, as though in sleep, and trembling in the forelegs. When stimulated she attempted to get up, but was unable to raise her body from the ground. Through the struggle the respiration became more marked and heavy, the animal breathing much as though in a deep sleep. After the struggle the pulse was 174 and fairly strong. At 7.10 a. m. the respiration was 36 and the temperature 101° F. Plate I, figure 1, shows the condition of the animal as she appeared at 7.15 a. m. At 8 a. m. she lay with her head extended on the ground, in much the same position as at 7.15. She raised her head for a few moments, then slowly dropped it with eyes half closed, as if in sleep. At 8.05 a. m. she held her head up, and apparently made an effort to walk. Her respiration was 36 per minute, noisy, and deep. Her sides trembled as she breathed. The pulse was 122. At 8.50 a. m. she got upon her feet and stood several minutes, then leaned against the fence and sank down again. At 8.55 a. m. she stood with her legs bent at the knees as though in an effort to balance herself. Her respiration was 36 and of the same character as before. There was some frothing at the mouth. Her ears hung low. Plate I, figure 2, shows the attitude of the animal at 8.57. At 10.30 a. m. she lay breathing as before and trembling. Her temperature was 103.3° F. At 10.35 a. m. she was raised upon her feet and then tried to walk, but was unable to stand, and lay down again. At 10.47 a. m. she was unable to get her breath and went into a spasm, in which her legs straightened out very much as though she had been poisoned by strychnin. At 10.48½ a. m. she was breathing again more naturally. She lay upon her side, trembling violently, with her hind legs extended rigidly. At 10.50 a. m. she was quiet again. At this time she appeared to be a little bloated. At 10.52 a. m. the muscles were rigidly contracted again, and the trembling became more violent; this was followed by a spasm, in which she had great difficulty in getting her breath. At 10.55 a. m. she quieted down again, and her respiration became more regular and deep. At 10.56 a. m. another spasm came on. At 10.58 a. m. she was quiet again, with pulse 174, strong, and regular. At 11 a. m. another spasm came on, but the animal soon became quiet. At 11.08 a. m. the head was thrown back, the heart fluttered, respiration stopped, and at 11.10 a. m. the animal was dead. For several minutes before death the heart action was weak, and just before death she was unable to get her breath. The muscles gradually relaxed, the head was drawn back, and the heart stopped.

An autopsy was made upon the animal immediately, but very little abnormal was found. The heart stopped in systole, and the brain and spinal cord were congested. Other than this the animal appeared to be normal.

TYPICAL CASE OF SHEEP NO. 201.

Sheep No. 201, a ewe weighing 71 pounds, was brought into the corrals for feeding on August 16, 1913. On August 17, at 9 a. m., she was given 100 grams of ripe dry lupine seeds of *Lupinus leucopsis*, the seed having been ground in a coffee mill and mixed with 100 grams of bran. At 9.30 a. m. this material had been eaten, and she was given 100 grams more of the ground lupine seed, mixed with bran as before. At 12.20 p. m. most of this material had been eaten. Her respiration was loud and deep, as in a sleeping animal. It was estimated that the animal had eaten altogether 175 grams of lupine seed, which would be the equivalent of 0.542 pound per 100 pounds of animal.

On August 18, at 7 a. m., the animal appeared drowsy and sleepy. At 7.15 a. m. she walked about a little, throwing the forelegs out and dropping them as though lacking control. She staggered a little as she walked and appeared more sleepy than an hour earlier. There were some contractions of the surface muscles of the body. Plate II, figure 1, shows the condition of the animal at this time. At 8.15 a. m. she was still upon her feet and able to walk around, but walked as though tipsy. When standing she appeared sleepy, the ears drooped, and the eyes were half closed. She stood with her legs bent at the knees and hocks. At 9.12 a. m. she still stood with the

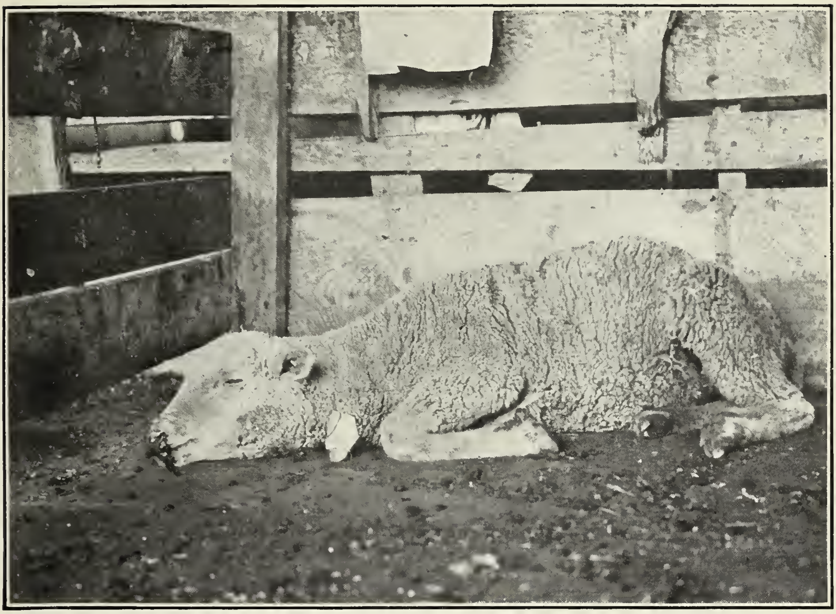

FIG. 1.—SHEEP NO. 184 AT 7.15 A. M., AUGUST 18, 1913.

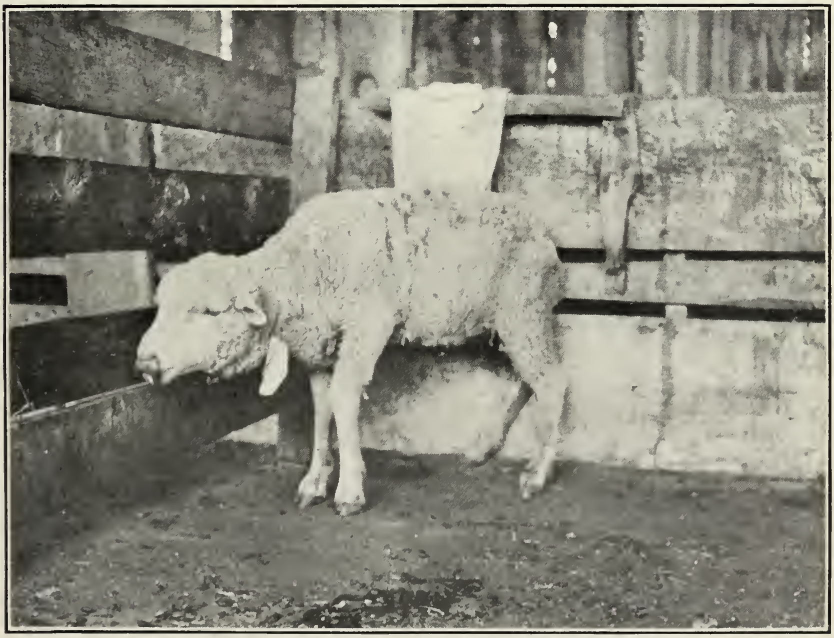

FIG. 2.—SHEEP NO. 184 AT 8.57 A. M., AUGUST 18, 1913.

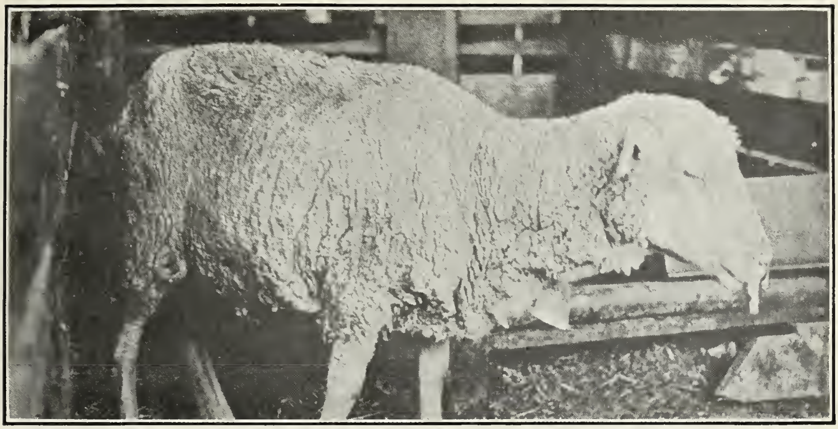

FIG. 1.—SHEEP NO. 201 AT 7.15 A. M., AUGUST 18, 1913.

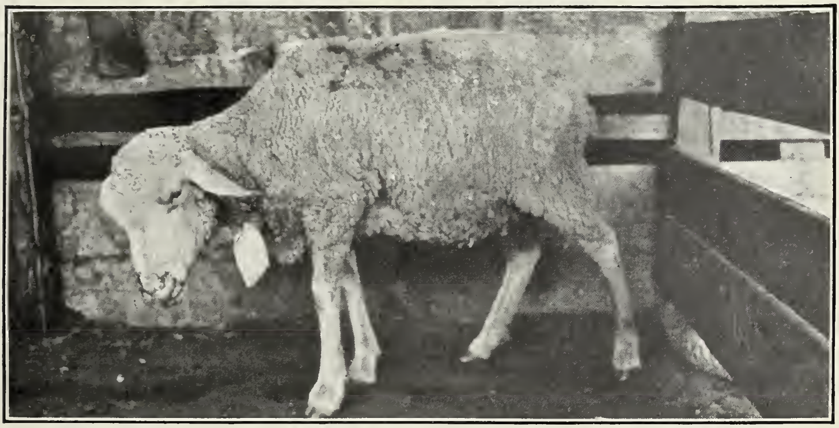

FIG. 2.—SHEEP NO. 201 AT 9.12 A. M., AUGUST 18, 1913.

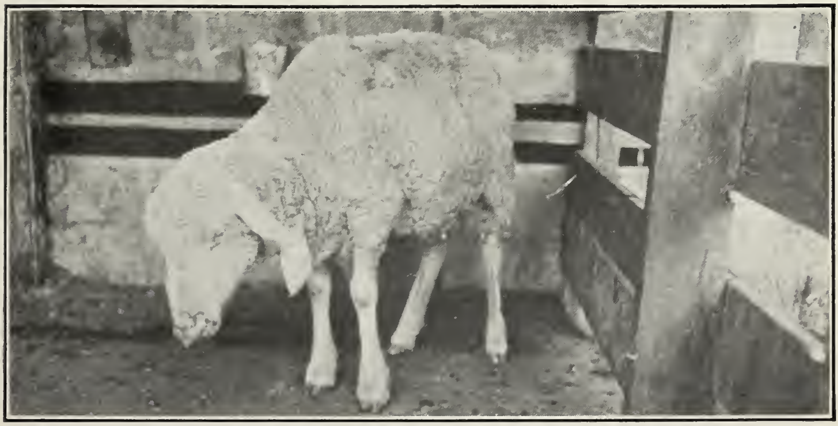

FIG. 3.—SHEEP NO. 201 AT 9.30 A. M., AUGUST 18, 1913.

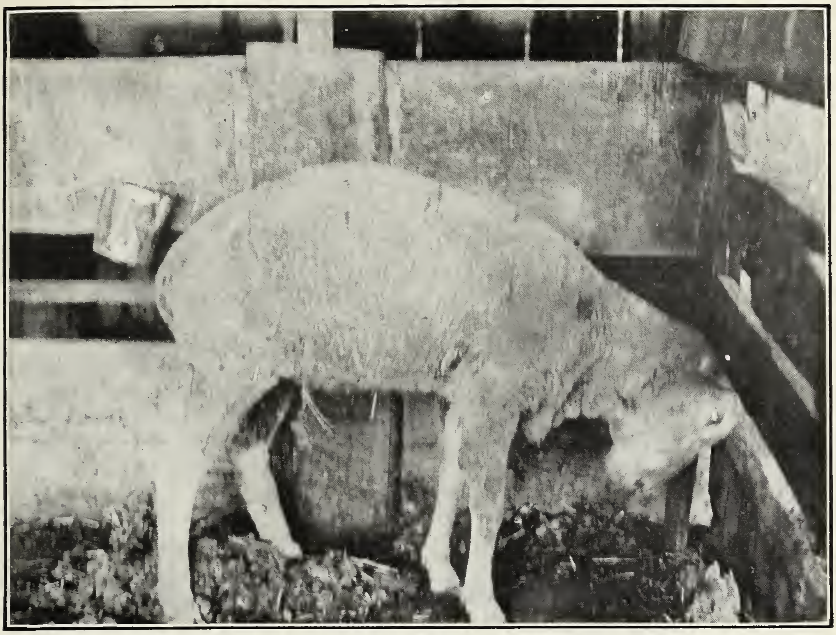

FIG. 1.—SHEEP NO. 253 AT 7.55 A. M., AUGUST 7, 1914.

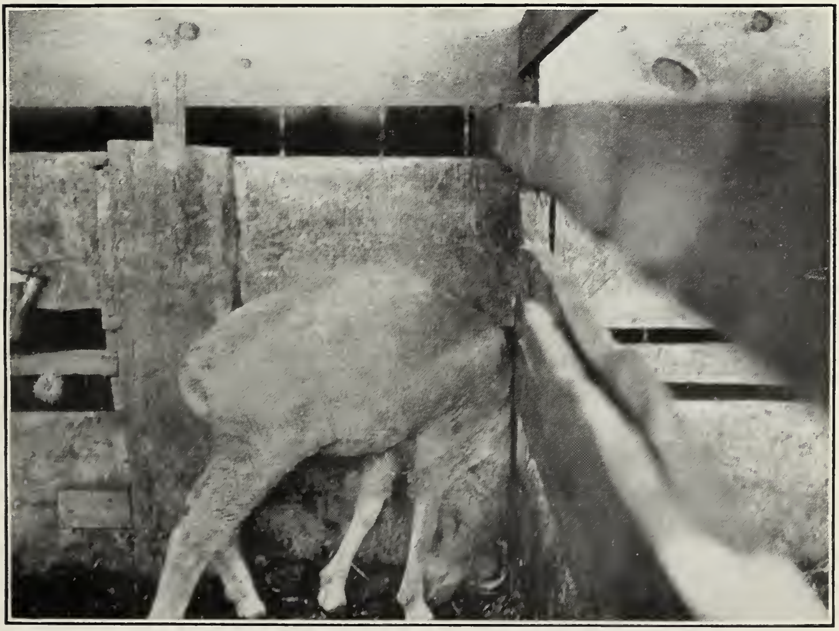

FIG. 2.—SHEEP NO. 253 AT 8.00 A. M., AUGUST 7, 1914.

same sleepy look and hanging ears, and occasionally walked about in an uneasy way. There was some lack of coordination of the muscles of the forelegs. Plate II, figure 2, shows the condition of the animal at that time, and Plate II, figure 3, shows the animal about 9.30 a. m. At 11.10 a. m. the condition was about the same as at 9.12. At 11.55 a. m. the animal was found upon her knees; she got up with difficulty, but was barely able to stand upon her feet. She had been gradually growing easier, and at 12.10 p. m. was down with her head upon the ground, apparently in a sleep. At this time she was given 5 grams of tannic acid in water, and 5 minutes later 10 c.c. of gin was given in an ounce of water. At 12.20 p. m. she was found down in a corner of the corral with her head under her body. She was helped up, but fell down again on her side in a convulsive spasm. At 12.25 p. m. she lay quiet; her respiration was 32, deep and labored, and her pulse 98, strong and regular. At 12.30 p. m. an attempt was made to get her upon her belly, but she rolled over on the other side. This was repeated several times. After several attempts she lay upon her belly with her nose extended on the ground. At 12.38 p. m. she tried to get upon her feet, but was unable to do so and went over on her side. Her legs straightened out, her head was thrown back in a strychninlike spasm, respiration stopped, the eyes rolled back, and at 12.41 p. m. the animal was dead.

At the autopsy a few petechiæ were found on the walls of the ventricles of the heart. The vessels of the small intestines were injected, and the brain was slightly congested. Nothing else abnormal was noticed.

TYPICAL CASE OF SHEEP NO. 253.

Sheep No. 253, a ewe weighing 62.5 pounds, was kept in the corrals August 5, 1914, for feeding.

On August 6, at 9.20 a. m., her temperature was 102° F., her pulse 60, and her respiration 16. From 9.30 a. m. to 10.05 a. m. she was fed with the balling gun 195.31 grams of seed pods of *Lupinus leucopsis.* The pods were collected July 16, before the seeds had ripened, and allowed to dry. In the process of drying the seeds were expelled. The pods were ground and 4 ounces of water was added to facilitate the feeding. This was fed in the ratio of 312 grams of pods to 100 pounds of animal. Allowing for the loss of weight in the pods due to drying, this animal received an equivalent of 2.755 pounds of fresh pods per 100 pounds of animal weight. The sheep appeared all right during the day and was watched until 11 p. m.

On August 7, at 5.50 a. m., her temperature was 100.6° F., her pulse was 96, and her respiration 21. The animal was found lying down with her head through the fence between the boards and swinging it from side to side. Her eyes were staring and expressionless. The femoral pulse was almost imperceptible. There was no evidence of dyspnœa. At 6.35 a. m. she was still lying upon her belly, with her head through the fence and swinging it from side to side. She was taken up and put upon her feet and walked a little distance, staggering as she walked. At 6.40 a. m. her pulse was 140, the heart beating very hard. Her temperature was 100.6° F. and her respiration 24. The animal was standing with her head lowered and swinging from side to side. She staggered across the pen, hit her head against the fence, and pushed forward, with her head partly twisted and under her body. As she lay down her head kept swinging from side to side. At 8 a. m. she was able to walk, but staggered as she moved. Her head was still swinging, pendulum fashion, from side to side. She pushed up against the side of the pen, preferably in a corner, with her head flexed toward the breast, so that at times she almost stood upon her head.

Plate III, figures 1 and 2, taken at 7.55 a. m. and 8 a. m., respectively, show the positions assumed. At 8.55 a. m. the sheep was lying quietly at the front of the pen. Her respiration was 80. She no longer swung her head from side to side and did not attempt to push it against the side of the pen. At 9 a. m. her temperature was 102.6° F., her pulse 102, and her respiration 86. The pulse was rather weak. There was some dyspnœa. She lay on her belly with her head to the left side and was quiet. At 9.15 a. m. she was up and about the corral. She would butt against the fence, then fall, extend the legs rigidly, and breathe rapidly. There was no rhythmic motion of the head at this time. At 9.40 a. m. she lay panting, with some frothing at the mouth. At 9.55 a. m. her pulse was 132, and strong in the femoral artery. Her respiration was 200, panting; her temperature was 103.2° F. She got her head into the corner of the corral and shoved forward until she almost stood upon her head. She struggled to push herself into this position, and as she was standing upon boards during the struggle her feet would sometimes slip and she would fall. After falling she would get up and start the butting process over again. At 10.35 a. m. she lay with her head to one side, the respiration being very rapid. She was disturbed, got up and started butting against the fence as before. This was kept up for two or three minutes, then she went down and remained lying with her head on one side. Plate IV, figure 1, shows her position at 10.40 a. m. At 10.55 a. m. the animal was up again and butting into the corners as before. She was drenched with 30 c. c. of whisky and an equal quantity of water. Her pulse was 132 and strong. At 11.55 a. m. she stood with her head low and part of the time on one side. Plate IV, figure 2, shows her in this position. There was a rapid chewing motion of the jaws; the motion was dorsiventral and not lateral. She bumped her head into the fence as before and

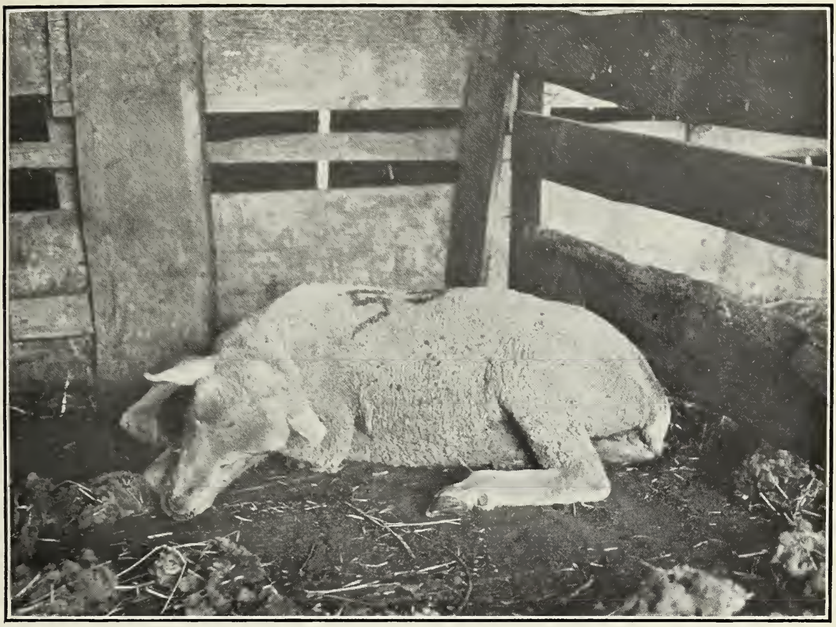

FIG. 1.—SHEEP NO. 253 AT 10.40 A. M., AUGUST 7 1914.

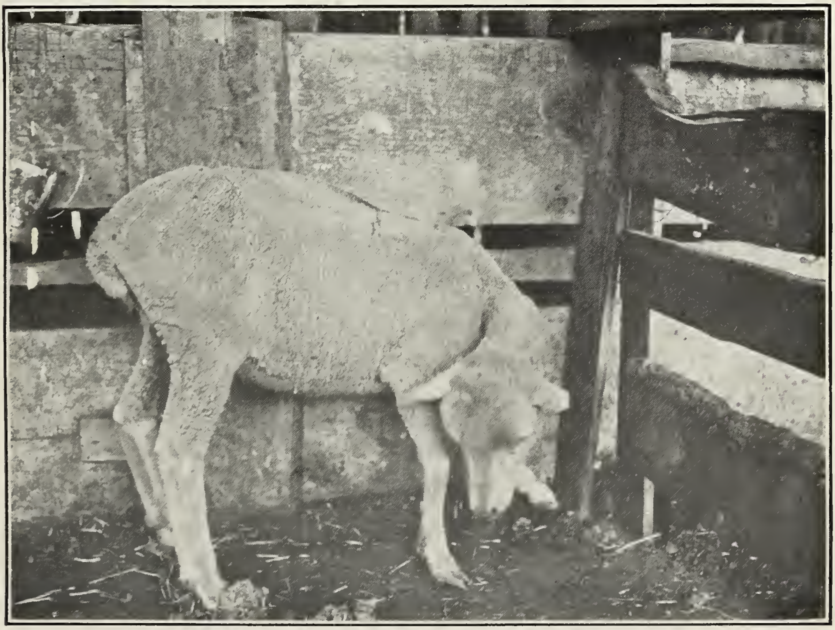

FIG. 2.—SHEEP NO. 253 AT 11.15 A. M., AUGUST 7, 1914.

staggered when she attempted to walk. At 11.22 a. m. she stood swaying from side to side. At 11.45 a. m. she was lying upon her belly with her head on one side, her respiration being about 200. At 11.50 a. m. she was up on her feet and commenced to butt into the fence again. She soon fell and lay panting. Her respiration was 160. At 11.57 a. m. she was lying upon one side and panting. At 12 noon she suddenly got upon her feet and started butting the corners, but immediately fell over, holding her head on one side. The chewing motions, as noted before, were marked. At 12.15 p. m. she got upon her feet, tried to run but fell over; she picked herself up, however, and started to butt into the corners. At 12.17 p. m. she fell down and lay quietly. At 12.30 p. m. she was on her side struggling in an attack of dyspnœa. At this time she was bled by cutting the angular artery of the eye. At 12.35 p. m. her respiration was 160. At 12.40 p. m. the movements of the jaws and lips still continued. At 1.10 p. m. she was struggling and the muscles of the flanks were trembling. Her pulse was so fast that it was impossible to count it. Her temperature was 107.6° F. At 1.11 p. m. she had fallen over on her side and was moving her body about. At 1.13 p. m. her respiration was barely perceptible, and at 1.15 p. m. it stopped. The movements of respiration and of the heart stopped at about the same time.

In the autopsy petechiæ were found upon the auricles of the heart. The lungs were congested. The walls of the ileum were injected, with some ecchymoses. The mesenteric blood vessels were injected.

LABORATORY EXPERIMENTS WITH EXTRACTS OF LUPINE SEED UPON MICE.

Preliminary experiments showed that mice are very susceptible to poisoning by extracts of lupine seed injected intraperitoneally. Accordingly, a few experiments were undertaken to determine by this method the relative toxicity of extracts of various parts of the lupine plant. Seeds, pods, and leaves of *Lupinus leucopsis* collected at Greycliff, Mont., in the summers of 1913 and 1914 were used for these experiments. The following is a description of the method used in preparing the extracts:

> Material was taken from each part of the plant which it was desired to examine, and all the samples were ground in the same mill set to the same degree of fineness. They were all ground the same day and at approximately the same time. From each form of material a sample of 20 grams was taken, placed in a flask, and macerated with 150 c. c. of Prolius's solution for 48 hours. The maceration of the different samples examined was begun and ended at the same time. Ninety c. c. of Prolius's extract was then taken from each flask, filtered, and evaporated down spontaneously. The residue of each was then extracted with 1 per cent of HCl, using 3 portions. The solution was filtered off, neutralized with Na_2CO_3, and made up to 10 c. c., so that 1 c. c. of the solution was equivalent to 1.2 grams of the sample.

These extracts were made by Mr. O. F. Black, chemical biologist in the Office of Drug-Plant and Poisonous-Plant Investigations, and were used in intraperitoneal injections upon mice. Table 2 gives the results.

TABLE 2.—*Relative toxicity to mice of the various parts of Lupinus leucopsis.*

Animal.		Part of plant.	Extract used.	Plant used.		Result.
Mouse.	Weight.			Weight.	Per 25 grams of animal.	
	Grams.		*C. c.*	*Grams.*	*Grams.*	
No. 27	24	Leaves	1	1. 2	1. 25	Death in 7.5 minutes.
No. 35	26. 5	do	.75	.9	.833	Death in 9.5 minutes.
No. 44	23. 5	do	.5	.6	.64	Death in 26 minutes.
No. 47	14	do	.15	.18	.322	Not sick.
No. 36	26. 5	Pods (seed removed)	.5	.6	.565	Death in 4.5 minutes.
No. 37	20	do	.25	.3	.375	Death in 6.5 minutes.
No. 45	19	do	.15	.18	.237	Not sick.
No. 38	15. 5	Pods (seed shed)	.25	.3	.482	Very sick; recovery.
No. 43	19. 8	do	.3	.36	.457	Sick; recovery.
No. 46	19	do	.35	.42	.552	Death in 11 minutes.
No. 39	24	Seed (1914 collection)	.2	.24	.25	Death in 12.5 minutes.
No. 40	19	do	.15	.18	.237	Sick; recovery.
No. 41	22. 5	Seed (1913 collection)	.2	.24	.266	Not sick.
No. 42	21	do	.25	.3	.357	Death in 14 minutes.

Table 2 shows that the amount necessary to kill a mouse on the basis of the standard weight of 25 grams is approximately as follows:

	Grams.
Leaves	0. 6 to 0. 64
Pods (seed removed)	.3 to .35
Pods (seed shed)	.5
Seeds, collection of 1913	.3 to .35
Seeds, collection of 1914	.25

Inasmuch as it is known from other experiments that the toxic and lethal doses are practically the same, it is fair to assume that this table gives, approximately, not only the lethal dose but also the toxic dose. From Table 2 it appears that the seeds collected in 1914 were slightly more toxic than those collected in the preceding year. Possibly a certain amount of the toxicity was lost in keeping. It appears also that the pods from which the seed had been shed were only about half as toxic as the seed. The pods from which the seed had been removed were considerably more toxic than the pods from which the seed had been shed, and the leaves were only about one-half to one-third as toxic as the seed. These figures do not conform very closely to those obtained in the field experiments upon sheep, but perhaps as closely as could be expected under the different conditions of experimentation. An especially interesting feature of this experiment was the definite proof obtained by Mr. Black by analytical methods of the presence of the alkaloids in the leaves, with the consequent deduction, confirmed by actual experiments, that the leaves are toxic. Inasmuch as the field experiments upon sheep were inconclusive in regard to the toxicity of the leaves, this is an important addition to the knowledge of the subject.

The field experiments gave little information as to the relative toxicity of the different species of lupines. There was nothing to indicate any difference in the toxic effect of those used in the feeding experiments. Accordingly, a few experiments were made on mice with extracts of the seed of the available species. Seeds of three American species were used, and through the kindness of Mr. Piper, of the United States Department of Agriculture, seeds were obtained of the three common European species, *Lupinus albus*, *L. angustifolius*, and *L. luteus*. Extracts of these lupines were prepared by Mr. Black, using exactly the same method as that employed in the preceding test of the seeds of *L. leucopsis*. A series of tests was made on mice by intraperitoneal injection of these extracts. Table 3 shows the results. In this table, for purposes of comparison, the experiments with seeds in Table 1 are included.

TABLE 3.—*Comparative toxicity to mice of the seed of different species of lupines.*

Plant.	Animal.		Amount used.		Used per 25 grams of animal.		Result.
	Mouse.	Weight.	Extract.	Plant.	Extract.	Plant.	
Lupinus leucopsis:		*Grams.*	*C. c.*	*Grams.*	*C. c.*	*Grams.*	
1914 seed	No. 39.	24	0.20	0.24	....	0.25	Death in 12½ minutes.
Do	No. 40.	19	.15	.18	....	.237	Sick; recovery.
1913 seed	No. 41.	22.5	.20	.24	....	.266	Not sick.
Do	No. 42.	21	.25	.3	....	.357	Death in 14 minutes.
Lupinus luteus	No. 49.	18.5	.15	.18	0.2	.25	None.
Do	No. 49.	....	.5	.6	.7	.8	Sick; recovery.
Do	No. 50.	21	.25	.3	.3	.36	Symptoms.
Lupinus albus	No. 51.	23	.5	.6	.54	.65	Death in 3 minutes.
Do	No. 52.	23.5	.2	.24	.21	.25	Death in 13 minutes.
Lupinus angustifolius.	No. 53.	24	.25	.3	.26	.3	Death in 19 minutes.
Do	No. 54.	27	.15	.18	.14	.17	Symptoms.
Lupinus leucophyllus:							
1913 seed	No. 56.	22.5	.25	.3	....	.335	Death in 6½ minutes.
Do	No. 57.	21.5	.15	.18	....	.2075	Symptoms.
Lupinus argenteus:							
1913 seed	No. 58.	21.5	.25	.3	....	.35	Death in 4 minutes.
Do	No. 59.	26.75	.15	.18	....	.168	Death in 6 minutes.
Do	No. 60.	19	.75	.09	....	.1185	Symptoms.

In regard to mouse No. 49, it should be stated that inasmuch as the first injection of 0.15 c.c. of extract produced no results, a second injection of 0.5 c.c. was given shortly afterward. From the known facts in regard to lupine poisoning it is not to be presumed that there was any appreciable accumulative effect from the preceding injection. Table 3 shows very clearly that by this method of experimentation *Lupinus albus* and *L. angustifolius* appear to be about equally toxic. *L. luteus*, however, is much less toxic, it being necessary to take probably three or four times the quantity in order to produce results. It may be noted in passing that *L. luteus* is the species which is said to be responsible for the so-called ictrogenic poisoning which occurs in northern Germany. In regard to the American species, *L. leucopsis* and *L. leucophyllus* are about equally toxic and do not differ much from *L. albus* and *L. angustifolius*. *L. argenteus* appears to be much more toxic than the other American species examined.

It should be noted that in these experiments on mice the animals died of respiratory paralysis, with marked dyspnœa, the heart sometimes continuing to beat as much as a minute after respiration had ceased. The work with extracts is of a preliminary character, and it is intended to prepare for future publication an extended study of the alkaloids and the effect of the extracts..

PART III.—DISCUSSION AND GENERAL CONCLUSIONS.

FAILURE TO POISON SHEEP IN 1910, 1911, AND 1912.

In the early work of the field experiments it was assumed that the lupines were sufficiently toxic to poison animals in the course of ordinary feeding. It was thought that if the animals were confined and given little or nothing of other food material and were abundantly supplied with lupine, symptons would appear if the plants were toxic.

There was little in American literature to indicate the probable dosage. Chesnut and Wilcox (1901, p. 108) state that 150 pods were fed to each of two sheep and both were fatally poisoned. Accordingly, in 1910 the sheep used were confined in corrals and were fed all they would eat. One animal, sheep No. 102, between July 6 and 30, ate 128 pounds of lupine tops, including leaves, flowers, and fruit, and another, between August 25 and September 7, ate 55.5 pounds of seed-containing pods, with no ill effects other than a loss of weight. Sheep No. 105, which received the 55.5 pounds of pods and seeds, was given on some days as much as 8 pounds.

The experience of 1911 was similar and with no more results. Although a large number of experiments were made in 1912, in only one case were there harmful results. This animal, sheep No. 180, was fed 0.85 pound of lupine seeds on September 15, and the next day it was found dead in the pasture. At that time, because of the large number of negative experiments, it was thought that the death of the animal must be due to some other cause than lupine poisoning. The more complete knowledge of the effect of lupine, brought out in the work of 1913 and 1914, makes it evident that this was a case of lupine poisoning. All the other cases of 1912 were negative.

In comparing the work of these years it will be noticed that in 1913 the feeding of seeds was done in a single day, and in most cases the quantity fed was eaten in a short time. This was true of sheep No. 180 in 1912, which ate the given quantity within an hour. In

1914 the experiments were by forced feeding, so that the animal received the total quantity in a short period of time; while in 1910 and 1911 some of the animals received large quantities, but the feeding was distributed over a long period. Although in some cases as much as 8 pounds was fed in a single day, this was eaten in a more or less leisurely way.

In 1912 two sheep, Nos. 175 and 168, were drenched with the fruit, No. 175 receiving 1.435 pounds and No. 168 4.198 pounds, and showed no symptoms, although the 1914 experiments indicated that the toxic dose of fruit is about 1½ pounds. Sheep No. 175, however, received its lupine in three doses, between 10.30 a. m. and 3.30 p. m.; it is possible that this animal might have been poisoned had it received the material in a single dose, as the quantity given was close to the toxic limit. But sheep No. 168 received 4.198 pounds, between two and three times the toxic dose as determined in 1914; this material was given in six doses, between 8 a. m. and 7 p. m. It seems probable that the only reason this animal was not poisoned was because of the length of time during which the material was given.

It appears to be a fair inference that the excretory apparatus of the sheep can take care of the toxic substance of the lupine provided the quantity given at any one time does not reach the toxic limit. It is hoped to carry on later detailed experiments to show just how this is done—experiments for which adequate facilities have not been available thus far. It is probable, however, that this excretory work is done largely by the kidneys, since preliminary experiments with other toxic substances upon sheep indicate that the kidneys are very efficient in the removal of some toxic substances. It has also been shown by others that the lupine alkaloids are found in the urine. The failure to get results in the earlier experiments was due to the fact that the sheep did not get at any time more than the excretory apparatus could remove before the toxic limit was reached.

LUPINE NOT A CUMULATIVE POISON.

The lupines as poisonous plants do not have a cumulative effect. This has an important bearing on range management of sheep, for it is evident that sheep may graze continuously on lupines with no bad results, provided the toxic limit is not reached at any one time. Inasmuch as the toxic dose is a fairly large quantity, and sheep do not ordinarily show any special fondness for the lupines, well-fed animals are not likely to be poisoned by lupines. It is only when, for some reason, they eat an unusually large quantity that losses occur. This is discussed in more detail under "Range conditions under which sheep are poisoned" on page 39.

TOXICITY OF DIFFERENT SPECIES OF LUPINE.

The field experiments give little information as to any difference in toxicity between the species of lupines. While only one of the two species used in the experiments with horses produced effects, viz, *Lupinus myrianthus*, the feedings of *L. comatus* were not conducted under exactly the same conditions, the period of feeding being considerably longer than in the experiments in which poisoning was produced by *L. myrianthus.*

The probable reasons why sheep were not poisoned on *Lupinus myrianthus* and *L. comatus* are discussed on page 28. Nearly all the experiments at Greycliff were on *L. leucopsis.* The field experiments on *L. argenteus* and *L. leucophyllus* were so few that it is not safe to make any deductions. It seems probable that in the experiments of feeding the seed of *L. argenteus*, the dosage was just a little too small, even granted that the plant is equally toxic with *L. leucopsis.*

The experiments with mice detailed on pages 25 to 28 indicate that the European species, *Lupinus albus* and *L. angustifolius,* are about equally toxic with *L. leucopsis* and *L. leucophyllus,* while *L. luteus* is much less toxic, the dosage probably being at least three times as great as that for the other species. Inasmuch as the experiments on mice were few in number, too much importance must not be attached to the results. They are interesting, however, as giving some indication of the probable comparative toxicity of the species examined. These experiments with mice give an indication of the probable toxicity of the leaves as compared with other parts of the plants.

TOXICITY OF LUPINE LEAVES FOR SHEEP.

Sheep No. 243 was an undoubted case of lupine poisoning. The symptoms were typical and it received only leaves. It was impossible, however, to verify this by other experiments. The other animals (Nos. 295, 266, 256, 290, and 306, with *L. leucopsis,* and Nos. 263 and 307 with *L. argenteus*) were fed much more, in some cases more than three times as much, without any effect whatever. It should be added that while all animals upon the range apparently graze upon lupine with impunity, sometimes eating very large quantities, there are cases when it seems probable that lupine leaves must be toxic. For example, cases of undoubted lupine poisoning in the Absaroka National Forest, examined by Dr. Hadleigh Marsh in the summer of 1914, apparently did not have an opportunity to obtain enough of the seeds to cause the difficulty. If it could be assumed that the leaves are sometimes toxic, these cases would be much more easily explained. Many similar cases of range poisoning have occurred where it was difficult to explain the loss except by assuming that the lupine leaves are toxic. Moreover, laboratory work, conducted with the assistance of Mr. O. F. Black, shows clearly that there is a large quantity of the alkaloid in the leaves, although less than in the seed.

A careful analysis of the cases of sheep fed with leaves offers no explanation for the difference in results, although many possible factors have been taken into consideration, such as difference in animals, difference in methods of administration, seasonal change of toxicity, etc. All that can be said at this stage of the investigation is that while lupine leaves are not always injurious they are toxic, and under some conditions—conditions which can not now be defined—they cause illness and death.. It is evident that no definite statement can be made as to the toxic and lethal dose of leaves for sheep.

TOXICITY OF LUPINE SEED FOR SHEEP.

Table 4 is a statement of the sheep poisoned by lupine seed in 1913, showing the quantity in each case which produced the result.

TABLE 4.—*Sheep poisoned by lupine seed in 1913.*

Feed and animal.	Date fed.	Pounds fed per 100 pounds of animal.	Result.
Unground seed:			
No. 209	Aug. 15	0.561	Sick; recovery.
No. 184	Aug. 17	.705	Death.
Ground seed:			
No. 210	Aug. 15	.268	Sick; recovery.
No. 201	Aug. 17	.542	Death.
No. 185	Aug. 31	.441	Do.
No. 212	Sept. 2	.245	Sick; recovery.
No. 203	Sept. 6	.439	Do.

Inasmuch as sheep No. 208 received 0.551 pounds of the unground seed without any toxic effect, it would appear that the dose received by sheep No. 209 (0.561 pound) with resulting illness, must have been very near the toxic limit. As the only sheep that died (sheep No. 184) received 0.705 pound, the lethal limit, so far as these experiments show, lies between 0.561 and 0.705 pound.

When ground seed was used, the dosage was much smaller, as would be expected. Sheep No. 212 was poisoned by 0.245 pound, and sheep No. 210 by 0.268 pound. Others were fed larger quantities without effect; for example, sheep No. 196 received 0.425 pound, and sheep No. 207, 0.423 pound, while several received 0.3 pound or more. Sheep No. 196, however, received its dose in 2 days, whereas the others received theirs in a single day. It seems that sheep may be poisoned on as little as 0.25 pound or may receive as much as 0.423 pound without effect.

The two cases of death resulted from doses of 0.543 and 0.441 pound. The general deduction from the experiments of 1913 on ground seed was that the toxic dose was between 0.25 and 0.5 pound, and the lethal dose about 0.5 pound, with the probability that in the average cases the lethal dose was somewhat more, perhaps nearly 0.6 pound.

It was considered that these experiments determined the dosage nearly enough for practical purposes, and in the experiments of administering ground seed in 1914, which were mainly with reference to the effect of antidotes, the dosage was intended to be heavy enough to produce serious illness, if not death. The general results showed that the estimate of dosage made in 1913 was approximately correct, and that the toxic dose is somewhat less than 0.5 pound, sometimes as low as 0.25 pound.

TOXICITY OF LUPINE PODS FOR SHEEP.

The number of experiments of feeding lupine pods was not sufficient to determine the dosage with any exactness. Sheep No. 253 died on August 6, 1914, from eating 2.755 pounds of pods. This material had been collected previously and dried, but the weight as given is the green weight, as the loss from evaporation was known. These were pods in which the seed was not yet ripe.

Sheep No. 301 died on August 28, 1914, from eating 2.041 pounds of pods which were collected after they had shed most of their seed; a few seeds, however, remained attached to the pods. The weight given is the dry weight, as there was no way of estimating the loss of water in drying. In all the other cases much smaller quantities were fed, and no intoxication resulted. It can only be said that the pods are distinctly toxic, but the dosage is much greater than of the seeds.

It may be added in this connection that in 1913 a careful computation was made of the relative weights of the seeds and pods in the fruit, and that, based on the result of this work, the toxic dose of pods would be 3.4 pounds. Without much doubt the toxicity of the pods varies at different seasons and probably is much reduced in the dried pods remaining attached to the plants in the late summer and fall.

TOXICITY OF LUPINE FRUIT FOR SHEEP.

By "fruit" is understood the pods with the contained seeds. A considerable number of experiments were made to determine the toxicity of the fruit as compared with the seed. Table 5 gives the results of these experiments. The term "Seed heads" means the fruits and the stems bearing them. In the cases listed under "Fruit, fully developed," the pods were picked from the stems.

The last four feedings under "Fruit, fully developed" were of very poor, locoed animals; consequently, the dosage (as computed according to weight) would be distinctly different from that computed for the same animals in a normal, healthy condition. This may possibly explain why in the cases of Nos. 251 and 280 the dosage, computed on the basis of a 100-pound animal, so much exceeds the lethal dose shown in the preceding experiments. For example, sheep No. 280 weighed 99 pounds earlier in the season, while at the time of the experiment it weighed only 84 pounds. If the dosage of material given September 4 were computed on the assumption that the animal had its original weight, it would reduce the amount given in the table to approximately the toxic or lethal dose of the preceding animals, and as the margin between no symptoms and toxicity is so small this animal would not differ materially from the others.

TABLE 5.—*Sheep given forced feedings of lupine fruit in 1914.*

Feed and animal.	Date fed.	Pounds fed per 100 pounds of animal.	Result.
Fruit, fully developed:			
No. 292	July 16	0.882	Not sick.
No. 291	July 17	.441	Do.
No. 277	July 18	1.322	Do.
No. 278	July 19	1.764	Death.
No. 238	July 20	1.543	Do.
No. 269	July 23	1.433	Not sick.
No. 240	July 24	1.543	Symptoms.
No. 297	do	1.433	Not sick.
No. 256	July 25	1.763	Death.
No. 231	Aug. 29	1.543	Not sick.
No. 235	Aug. 31	1.541	Do.
No. 251	Sept. 2	1.761	Do.
No. 280	Sept. 4	1.901	Do.
Seed heads, fully developed:			
No. 255	July 28–29	1.033	Do.

It is evident from Table 5 that approximately 1½ pounds of fully developed fruit will produce symptoms or death in a 100-pound sheep—that is, it takes three times as much of the fruit to poison as of the seed.

SYMPTOMS.

Some of the sheep poisoned by lupine, froth at the mouth, but this is by no means a universal symptom. The most noticeable and significant symptom is the character of the breathing. In the milder cases the breathing is heavy and labored, subsiding into a condition of coma in which the animal may continue for a long time, snoring as though in a deep sleep. If able to stand, the animal may fall over in its sleep. In the more acute cases, there are severe attacks of dyspnœa, during which the animal throws itself about violently in its attempts to breathe. During these attacks the tongue and mouth become cyanotic from the congested peripheral blood vessels. Sometimes in these attacks of dyspnœa the animal dies in convulsions in which the limbs are extended rigidly, much as when poisoned by strychnin. In other cases the condition of coma deepens until the animal dies without a struggle. The convulsive attacks of dyspnœa, however, may be considered typical of lupine poisoning. Drooping of the ears is noticeable in the early stages of the poisoning. In many cases the poisoned animal is continually pushing its head against surrounding objects. In corral cases the sheep pushes against the fence, lowering its head so that sometimes the animal almost stands on its head. These attitudes are shown in Plate III, figures 1 and 2. If moved from one point it may immediately push up against the fence in another place, sometimes throwing its head through an opening and remaining in that position. Sometimes the head will be swung rhythmically from side to side.

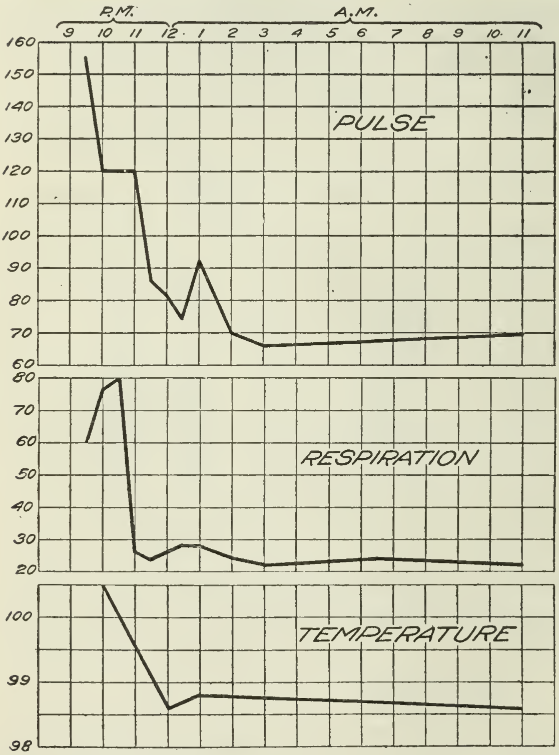

Fig. 2.—Curves showing the changes in pulse, respiration, and temperature of sheep No. 185.

Generally when sheep become affected on the range they run about in a frenzied way, butting into other animals and objects. Handling the animals under such conditions excites them to such an extent as seriously to interfere with their chances of recovery. When attempts were made to administer remedies by drenching, it was found that the animals lost more by the increased excitement than they gained from the remedy. If the sheep does not die in the period of excitement, it staggers until it falls, then lies in a stupor, which in the fatal cases gradually grows deeper.

The pulse and respiration are very high in the acute stages of the intoxication, but later are not very different from normal, except that the pulse rate is frequently increased just before death.

The intoxication produces no effect on the temperature, but in long-continued cases the temperature gradually falls, sometimes to between 98° and 99° F. The curves (fig. 2) showing the changes in the rate of the pulse, respiration, and temperature of sheep No. 185 are fairly typical of the changes which ordinarily take place.

Associated with the condition of excitement there is frequently more or less violent trembling. Nausea is not often exhibited. Bloating occurs in some cases, probably being more likely to occur when the sheep eat very largely of lupine leaves.

Especially characteristic of lupine poisoning are: (1) Excitement, leading to running about and butting into other objects; (2) convulsions, accompanying the attacks of dyspnœa; and (3) heavy breathing, sometimes accompanied by snoring.

There is considerable variation in the length of time which elapses between the feeding of lupine and the incidence of symptoms of poisoning. In some cases symptoms appeared in 1 or 2 hours, while there were other cases in which nearly 24 hours passed before symptoms were noticed. It is evident that rumination does not necessarily precede the symptoms; in fact, there was no evidence that rumination occurred in any of the experimental sheep, although as they were not under constant observation it could not be said positively that rumination never took place.

It can be seen from the experimental work that sheep upon the range, when poisoned by lupine, may not exhibit symptoms until they have left the source of their trouble far behind.

In the autopsies, the peripheral blood vessels were found strongly congested. The left heart was usually strongly contracted, and upon the surface of the heart in most cases were petechiæ. The lungs were congested, and sometimes the liver. The blood vessels of the brain were somewhat congested, and generally the blood vessels of the inner wall of the ileum were more or less congested.

The immediate cause of death is evidently respiratory paralysis. Death may follow very quickly after the first symptoms, or the animals may live for 2 or 3 days.

As noted in the description of the experiments of intraperitoneal injection of lupine extracts in mice, the animals died of respiratory paralysis, showing symptoms which were comparable with those exhibited by sheep.

The preceding details of symptoms are those exhibited by sheep. The experiments with horses were so few that no complete picture can be given. The distinct symptoms noted were twitching of the surface muscles, constipation, dullness, and a tendency when walking to lift the fore feet high.

Dr. A. D. Knowles, of Butte, Mont., has recently treated some interesting cases of lupine poisoning of horses. Dr. Knowles has made a very careful study of these cases and has done some experimental feeding, making autopsies and having microscopic preparations made of the diseased organs. These horses exhibited symptoms comparable with the "ictrogenic" poisoning reported in Germany, especially noticeable being the atrophy of the liver accompanied by a yellowing of the connective tissues.

While some American authors have distinguished between "acute" and "chronic" lupine poisoning, their statements appear to have been drawn from European sources, and Dr. Knowles has apparently been the first to note and record definitely cases which can be diagnosed as instances of "lupinosis" or ictrogenic poisoning. The clear-cut evidence presented by Dr. Knowles seems conclusive and makes it probable that other similar cases will be found, although it does not seem likely that lupine causes large losses of horses in the aggregate.

PATHOLOGY.

Some typical pathological material from the autopsies was examined by Dr. Formad, of the Bureau of Animal Industry. A large amount of material remains for examination, which may be made the subject of a future report. The general character of the preliminary report was confirmatory of the results of the macroscopic examination of the cases.

There was fullness and congestion of the pulmonary capillaries.

The hepatic cells showed the presence of a mild degree of cloudy swelling and some œdema.

The kidneys showed a slight degree of cloudy swelling of the epithelium, and in some cases fullness between the convoluted tubules of the cortex and overdistension of the capillaries of the medulla accompanied in places by outwandering of the leucocytes and diapedesis of the red-blood corpuscles, indicating a marked congestion.

COMPARISON OF "LUPINOSIS" AND POISONING OF SHEEP BY AMERICAN LUPINES.

The symptoms of lupinosis are described in detail by a number of European authors, e. g., Zürn (1879), Arnold and Schneidemühl (1883), Roloff (1883). Summaries are given by Dammann (1902, p. 340–341) and Hutyra and Marek (1913, p. 524–525).

The characteristic symptoms are:

(*a*) Loss of appetite.
(*b*) Fever in the first stages of the disease.
(*c*) Weakness.
(*d*) Cerebral excitement; thrusting the head against a wall and into corners.
(*e*) Gnashing of teeth.
(*f*) Pain in hind part of body.
(*g*) Diarrhea; ill-smelling excrement.
(*h*) Sometimes bloody urine, containing bile and albumen.
(*i*) Yellowing of conjunctiva and visible parts of mucous membranes in most cases, but not in all.
(*j*) In some cases swelling of ears, eyelids, lips, and nose.

(*k*) In autopsies there is seen a citron-yellow color of the body tissues, hemorrhages in various parts of the body, especially in the mucous membranes of the alimentary canal, the peritoneum, omentum, mesentery, the epicardium and endocardium, frequently fullness of gall bladder, generally an acute yellow liver atrophy, while in other cases the whole picture presents an appearance of acute phosphorus poisoning.

The German authors distinguish between acute and chronic cases, the symptoms being the same, but in the latter the liver exhibits chronic interstitial inflammation, leading to atrophy of the organ, this being accompanied by nephritis and enlargement of the spleen.

It will be noticed that the laboratory results obtained by Sollmann and by Clawson and Black agree very well with the field experiments with sheep, but differ very distinctly from the symptoms of lupinosis. The fever and jaundice which are especially characteristic of lupinosis have never been observed in sheep in America, either in experimental feeding or in poisoning upon the range. It must be concluded that ictrogen is not the cause of loss of sheep on the ranges of the United States, but that the poisoning is due to the alkaloids in the lupines.

The symptoms in the corral experiments and in range cases are distinctly those of alkaloidal poisoning. The question naturally arises as to the explanation of the difference between the poisoning of animals as exhibited in Germany and in the United States. The lupines examined in Germany possess alkaloids which are similar to those found in the American lupines, if not identical with them, and yet few clear cases of alkaloidal poisoning of domestic animals have been reported, while in America there has been no poisoning from ictrogen. In the absence of any determination of what ictrogen really is or how it is formed, only a hypothetical explanation can be given. If it is granted that ictrogen is the cause of lupinosis and if the opinion is accepted, which seems to be held by the later authors, that ictrogen is formed by the action of microorganisms upon the lupine, a possible explanation lies in the different conditions of the countries. The European lupines are cultivated plants, grown and handled like hay. The poisoning cases are caused by lupine that is exposed in the mass, and sometimes under conditions favorable to the growth of microorganisms. The American lupines are wild plants, which grow in a somewhat scattered manner; they are not collected in masses, and consequently do not have an especially favorable environment for the growth of microorganisms. Moreover, it is very possible that the particular organisms which produce the toxic substance in Europe are not present in this country; of this nothing can be said positively, for no one has yet been able to demonstrate that any specific organism or group of organisms is responsible for the hypothetical substance ictrogen. Therefore, on the supposition that there is such a substance as ictrogen, or lupinotoxin, it seems possible that it would not be produced in America, at least under range conditions.

The fact that there is so little evidence that domestic animals in Europe suffer from the alkaloids of lupine may be explained by the different way in which the animals are handled. It is shown elsewhere in this paper that lupine poisoning of sheep on the western ranges is ordinarily associated with deficiency in the food supply. Rarely, if ever, are well-fed sheep poisoned. It may be assumed that the sheep in Germany that feed upon the lupine are stall-fed or pasture-fed and eat somewhat at leisure, so that seldom would they be likely to reach the toxic limit in a single feeding. In this connection, however, it may be noted that some of the symptoms mentioned by the German authors resemble those of alkaloidal poisoning, and, granted that ictrogen is the principal cause of the losses, it is possible that there is a certain amount of alkaloidal poisoning in addition. This would account for the nervous symptoms described by the German authors, for these correspond to the phenomena exhibited by western sheep suffering from the lupine alkaloids.

It should be noted in this connection that the work of Dr. Knowles mentioned on page 35 seems to show that under some conditions ictrogenic poisoning of horses may occur in America.

The exact relationship between poisoning by lupine alkaloids and ictrogenic poisoning is far from clear, and it is to be expected that the chemical investigations which are now being carried on by the United States Department of Agriculture will aid in clearing up this subject.

REMEDIES.

It was hoped that some remedy might be found by which recovery from lupine poisoning might be aided, but the results of the experimental work in this direction were disappointing. Whisky, gin, and atropin were tried, with no beneficial results. Caffein and Epsom salts were used to increase excretion, but without any advantage. Tannic acid and sodium bicarbonate were used as antidotes. In the publication on Zygadenus,[1] there is a discussion of reasons why the use of antidotes in a drench in any ordinary method of administration should not be expected to be beneficial. As in the work on Zygadenus, experiments were made of giving sodium bicarbonate in frequently repeated doses. This was tried in four cases (sheep Nos. 297, 254, 296, and 269). Sheep No. 269 received 0.772 pound of seed and died in spite of the remedy, but sheep No. 296 received 0.666 pound, considerably more than the toxic dose, and was not sick. This animal received the sodium bicarbonate every half hour, while sheep No. 269 received it at hour intervals. There seems to be little doubt, as in Zygadenus poisoning, that if the sodium bicarbonate can be administered at intervals frequent enough to catch the toxic principle as it enters the fourth stomach, recovery may be aided. This is of considerable theoretical interest, and the method might be used in order to save an especially valuable animal, but, of course, range animals can not be treated in this way, for the herder may have a large number of sheep sick at the same time. It is not unusual for 200 or 300 cases to occur suddenly, and any remedy which involves the administration of more than one or two doses is useless.

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[1] U. S. Dept. of Agr. Bul. No. 125, p. 41.

Herders frequently bleed sheep poisoned by lupine and claim good results. There seems no logical reason for this, however, and the experience of the writers at the field station leads them to consider bleeding as harmful rather than beneficial.

RANGE CONDITIONS UNDER WHICH SHEEP ARE POISONED.

It must be recognized that corral experiments, while superior to laboratory work in unraveling the complex problems of plant poisoning of domestic animals, do not cover the conditions of range poisoning. It is sometimes very difficult to decide to what extent the results of intensive corral feeding can be used in the explanation of range phenomena. Laboratory and corral experimentation are, of course, essential in such a study, and may give, in fact do give, fundamental information. An intimate acquaintance with range conditions is, however, necessary for the practical elucidation of these problems. Such an acquaintance with range conditions is somewhat difficult for the scientific investigator to acquire. Sheep are grazed in locations situated at long distances from regular avenues of travel or communication, and they are also moving from place to place. Cases of poisoning are reported, perhaps, some days after the trouble has occurred, and investigation at that time is likely to be useless. It is very difficult for the investigator so to locate himself as to be able to see these cases when they occur. These difficulties doubtless explain why there has been so little exact knowledge of the conditions surrounding the losses. There has been, moreover, no way of placing a correct valuation on the reports made by sheep herders and owners. The average sheep herder does not have a high order of intelligence, and this has led to an underestimate of the testimony of these men, for the fact has been overlooked that many of them are keen observers with a practical knowledge of conditions far superior to that of the average scientific investigator. The writers of this paper have had long and intimate acquaintance with the western stock ranges, but they have frequently been put to shame by the wonderful, almost instinctive, readiness with which an experienced sheepman will unerringly recognize slight symptoms of disease in the members of his flocks. The writers were fortunate in being able to observe many range cases, and the conditions under which poisoning may occur seem now quite clear.

It was early recognized that lupine poisoning ordinarily occurs only when hungry sheep graze upon the plants. Well-fed bands are rarely, if ever, poisoned. This statement, it may be said in passing, can be made general and covers practically all poisonous plants. If sheep are taken from the cars and turned into a pasture abundantly supplied with lupine, disastrous results are likely to occur. In July, 1914, 400 sheep, out of a band of 4,000, were lost near Lakeview, Oreg. The matter was investigated by Mr. Norman G. Jacobson, of the Forest Service, who found that the sheep had been driven 34 miles in four days with a scarcity of forage. On July 25, after a day's drive of 10 miles, they were turned into a 10-acre pasture which, investigation showed, contained little but sagebrush and lupines, and the lupines were in pod. The sheep, of course, ate the lupines and with resulting loss. Many losses have occurred in the fall when sheep are coming down from the mountain ranges and have been caught by snow. On such occasions the fall of snow may cover the grasses, but leave the lupines exposed. Hungry sheep coming upon such an area may eat enough of the lupines to produce poisoning. In the fall of 1913 a sheep owner in Montana lost 300 sheep in this way.

An area in the Caribou National Forest was investigated where annual losses have occurred. It was found that the sheep coming from the mountains pass through thick patches of lupine and eat it greedily. The fact that the lupines are in pod at the time of the drive makes the matter worse. In 1911, an especially disastrous year, one outfit lost 1,000 head in this locality.

And yet, in spite of these known cases of severe loss, sheep sometimes graze on lupine through a good part of the season and with no harm. Except as they are especially hungry sheep rarely, if ever, eat enough of the lupine to cause trouble. Poisoning is much more likely to occur if sheep are hurried over a lupine area, for then in their eagerness and jealousy of each other they seize upon the lupines, which are more easily reached than the grasses. Generally speaking, it is much better to drift sheep over a lupine area than to drive them. It may be noted that sheep that are new to a locality are much more likely to eat too much of the lupine than those that are accustomed to the country.

An attempt was made in 1912 to demonstrate in an experimental way that hungry sheep may be poisoned when they feed upon lupine. A bunch of 11 sheep were kept without food for 36 hours and then, during one day, were driven 12 to 15 miles with very little opportunity to eat. About 5 p. m. they were brought to a thick lupine patch and allowed to graze. They fed until about 8.30 p. m., when they were bedded down. They were up and feeding again at 12.15 a. m. and were grazing most of the time until 6.30 a. m., with the exception of the hour from 4 to 5. To the disappointment of the observers none of the animals was poisoned. It was noticed, however, that while a good deal of lupine was eaten they did not take to it greedily and preferred the grass, which was in fair abundance.

In thinking over the experiment later, it seemed probable that the fact that the sheep were allowed to feed freely, combined with the abundance of grass, might explain the lack of results. It was therefore decided to repeat the experiment with the difference that the sheep should not be allowed to feed freely upon a lupine patch, but should be kept moving back and forth, the idea being that in this way they might snatch at the lupine as the most prominent plant. An experiment of this kind was tried July 31, 1914. Thirty-six sheep were corralled at night and kept in until 2 p. m. the next day with no food. At 2 p. m. they were driven about a mile to a lupine patch having an abundance of pods and seed. It proved to be an unfavorable time for such an experiment, for it was very hot and the sheep would not feed until about 7 p. m. They grazed until about 8 p. m. and were kept on the move all this time. They were driven back to the corrals. The time of grazing was so short that it was assumed the experiment was a failure, and the sheep were not observed during the night. The next morning sheep No. 241, which had been observed as one of those eating the most lupine, was found down, and a little later it died, the symptoms and autopsy indicating that it was, without doubt, a lupine victim. The outcome of this experiment was considered to be a confirmation of the general explanation of range poisoning as given before.

TREATMENT OF RANGE ANIMALS TO AVOID POISONING.

From what has been said of the conditions under which range poisoning occurs, it is evident that much of the loss can be prevented by proper management of the bands.

Sheep should never be taken from the cars to a pasture having much lupine. It is cheaper to buy hay. After long drives with insufficient forage avoid grazing grounds which are covered with lupine. If it is necessary to drive sheep over lupine patches, do not hurry them, but allow them to spread out and drift across. Special care should be taken in the fall, when the grass may be covered by a fall of snow. In the treatment of the flocks remember the general fact, which is applicable in regard to all poisonous plants, that well-fed sheep are not likely to eat injurious plants. Conditions under which sheep get ravenously hungry should, if possible, be avoided.

Herders should recognize the fact that the pods and seeds are especially poisonous and that, consequently, poisoning is more likely to occur at the time when the plants are in fruit and in seasons when the fruit is most abundant. In very dry seasons frequently little fruit is matured, while a wet season, especially a wet spring, may cause a heavy production of fruit.

SUMMARY.

(1) Lupines have been cultivated and used from the time of the ancient Greeks and Romans, but their poisonous properties have been recognized only in very modern times. Heavy losses of domestic animals were reported in northern Germany in 1872 and the succeeding years.

(2) While chemists have shown the presence of poisonous alkaloids in the lupines, the losses in northern Germany have been considered by investigators as due not to the alkaloids but to a hypothetical substance known as ictrogen.

(3) An investigation by Dr. Sollmann showed the presence of alkaloids in American lupines, and pointed to the probability that most, if not all, the poisoning of live stock in America was due to these alkaloids and not to ictrogen.

(4) Extended field work has verified the conclusions of Sollmann and has shown that all aerial parts of the lupines examined are poisonous, the seeds being the most toxic, then in order the pods and leaves. This has been confirmed by preliminary experiments with extracts upon mice.

(5) The toxic substance is excreted by the kidneys; the intoxication is not cumulative, and animals may eat comparatively large quantities with no ill results, if the toxic limit is not reached at any one time. Inasmuch as the toxic and lethal limits are nearly the same, the prognosis for poisoned animals is not favorable.

(6) There is no form of remedial treatment that can be used advantageously for range animals. Poisoning in most cases can be avoided, even where the plant is abundant, by careful handling of the flocks, especial care being taken to see that hungry sheep are not grazed on fields where there is much lupine.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 406

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WM. A. TAYLOR, Chief

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DISTINGUISHING CHARACTERS OF THE SEEDS OF SUDAN GRASS AND JOHNSON GRASS.

By F. H. Hillman, *Assistant Botanist, Seed Laboratory.*

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INTRODUCTION.

The close relationship of Sudan grass and Johnson grass leads to a pronounced similarity in their seeds. The two kinds of seed can be distinguished, however, when their comparative size and certain features of their appearance due to differences in development are considered. Oakley[1] and Vinall[2] have referred to these characters as useful in distinguishing these two kinds of seeds.

When properly interpreted, the distinguishing characters are believed to be sufficiently reliable to make possible an accurate quantitative analysis of a mixture of the two kinds of seed, even though unhulled grains of both grasses are present.

When the seeds of the two kinds are under observation, the larger size of the Sudan grass seeds, including the hulled grains, is readily noticeable. The lighter color of the hulled grains is also evident.

Distinguishing characters presented by either of the two kinds of seed observable in the absence of the other depend chiefly on a difference in the development of the plants preparatory to seed fall. This may best be understood by first considering the structure of the terminal clusters of the general seed cluster, or inflorescence taken collectively. One of these seed clusters, shown in figure 2, illustrating

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[1] Oakley, R. A. Some new grasses for the South. U. S. Dept. Agr. Yearbook, 1912, p. 495–504, pl. 65–70. 1913.

[2] Vinall, H. N. U. S. Dept. Agr., Farmers' Bul. 605, p. 15. 1914.

Johnson grass, is seen to bear several seeds (ripened spikelets) attached directly (sessile) at the nodes of the jointed axis (rachis) of the cluster. These are indicated in figure 2 by *a*, which shows them as occurring along only one side of the axis. Accompanying these fertile or grain-bearing spikelets, which constitute the greater part of the unhulled commercial seed, are several slender, sterile spikelets (*b*), each elevated on a stem or pedicel (*d*) which is attached with a fertile spikelet at a node of the rachis. It is to be noted that the terminal fertile spikelet is accompanied by two sterile spikelets with their pedicels. It is especially to be noted that in the figure each node and the apex of each pedicel are marked by a distinct cross line indicating the suture (*e*) at the articulation or junction of each rachis segment and of each pedicel with its spikelet.

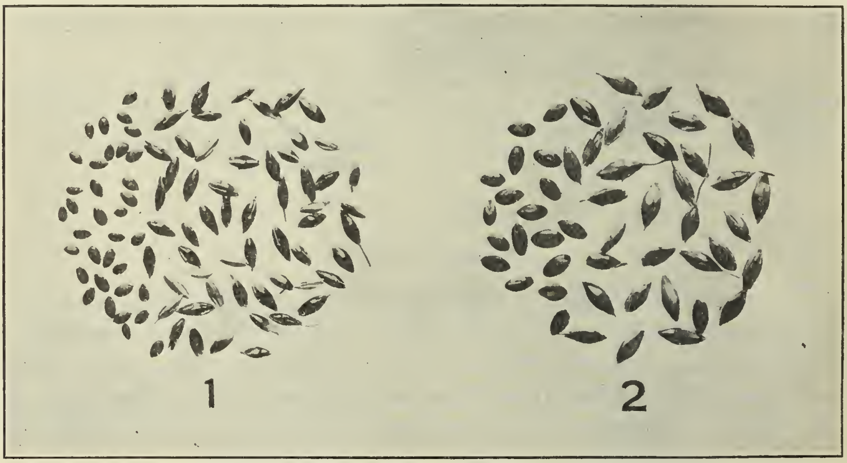

FIG. 1.—Seeds of Johnson grass (1) and Sudan grass (2). Hulled grains appear at the left of each group. (Natural size, from a photograph.)

It is the normal habit of the seed clusters of Johnson grass at maturity to break apart at these sutures, thus providing for the fall of the seed. Each rachis segment and accompanying pedicel remain attached to a mature spikelet or unhulled seed. Terminal spikelets retain the two pedicels. The rachis segment and pedicel or the two pedicels may be referred to collectively as the appendages of the seed.

In Sudan grass the terminal seed clusters in general structure are essentially the same as in Johnson grass. They differ, however, in being devoid of a suture at the nodes of the rachis and apex of the pedicels. In consequence, the seed fall does not uniformly result from separation at the articulation, but rather from the breaking of the rachis segments and pedicels at their weakest point, usually near the center (fig. 3, *c*). Most of the unhulled seeds therefore have a short stem (fig. 3, *a*).

What appear to be exceptions to the general rule of seed fall occur in both kinds of seed, but the presence or absence of the distinguishing suture is evident under a good magnifier.

DISTINGUISHING CHARACTERS OF THE SEEDS OF SUDAN GRASS.

Sudan grass seeds in the hull (fig. 3, *1*) vary from eighteen one-hundredths to twenty-five one-hundredths of an inch in length, exclusive of the short stem. Most of the seeds bear at the base of each a short stem (fig. 3, *a*), which is jaggedly broken at its extremity. This stem represents the upper portion of a rachis segment and is expanded at its articulation with the spikelet, or seed. The articulation may be marked by a slight constriction (fig. 3, *b*), but it has no distinct suture. The appendages of the spikelet usually are jaggedly broken and not expanded at the apex (fig. 3, *c*). The missing portion corresponds to the short stem of the spikelet described.

The seed hull is mainly straw colored or light tawny. Many seeds are tinged or spotted with brown. Some are tinged or spotted with red. The darkest are blackish brown. In general, commercial seed has a smaller proportion of reddish and blackish brown seeds than Johnson grass.

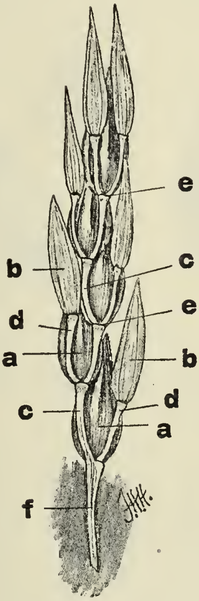

FIG. 2.—Seed cluster of Johnson grass, enlarged: *a*, *a*, Fertile spikelets; *b*, *b*, sterile spikelets; *c*, *c*, axis, or rachis, of the cluster; *d*, *d*, pedicels of sterile flowers; *e*, *e*, sutures at the articulation of spikelets with the axis; *f*, branch of the inflorescence bearing the seed cluster.

The hulled grains (fig. 3, *2*) vary from thirteen one-hundredths to eighteen one-hundredths of an inch in length and are light reddish brown. They are larger, more commonly elliptical in outline, and lighter colored than in Johnson grass. Even in the smaller grains the embryo is relatively larger than that found in Johnson grass seeds.

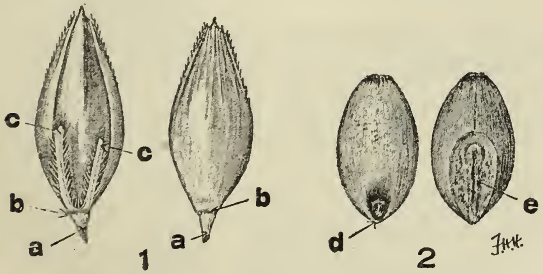

FIG. 3.—Sudan grass seeds, enlarged. Unhulled seeds, spikelets (1); hulled grains (2): *a*, *a*, Seed stem; *b*, *b*, constriction at the junction of seed and stem; *c*, *c*, appendages of the seed with broken apexes; *d*, scar of the grain; *e*, embryo.

DISTINGUISHING CHARACTERS OF THE SEEDS OF JOHNSON GRASS.

Johnson grass seeds in the hull (fig. 4, *1*) vary in length from fifteen one-hundredths to twenty-two one-hundredths of an inch. Most of the seeds have a smooth, rounded, and light-colored scar at the base. The appendages of the seed (fig. 4, *b*) are mostly entire, expanded, cup shaped, and smooth at the apexes, corresponding with the scar at the base of the seed. The uniformly smooth border of the expanded, cup-shaped apex, together with the smooth seed scar, results from the normal separation of the seed along a definite suture.

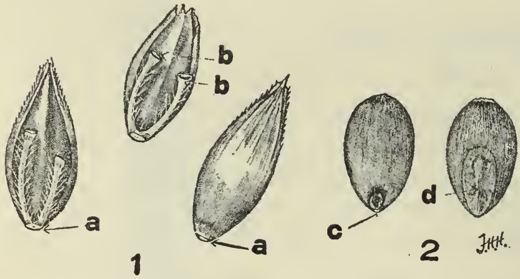

FIG. 4.—Johnson grass seeds, enlarged. Unhulled seeds, spikelets (1); hulled grains (2): *a, a*, Scar of the hull; *b, b*, appendages of the seed with expanded, cup-shaped apexes; *c*, scar of the grain; *d*, embryo.

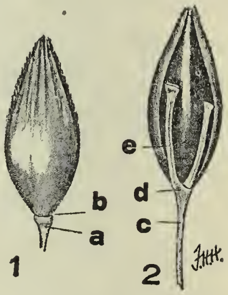

FIG. 5.—Stem-bearing seeds of Johnson grass, enlarged: (1) A seed in which the stem (*a*) is a portion of a rachis segment. The suture (*b*) at the junction of the stem and seed is evident. (2) A seed (the lowest of the cluster) in which the longer stem (*c*) is a part of the cluster branch. No suture occurs at the junction (*d*) of the branch and the first rachis segment (*e*). The opposite side of such a seed shows the suture, as at *b*.

The prevailing color of mature seed hulls is blackish brown. Many seeds are partially or wholly reddish. Some are straw colored. A few are tawny or light brown.

The hulled grains (fig. 4, *2*) vary from eight one-hundredths to twelve one-hundredths of an inch in length. They usually are oval, sometimes oval-elliptical in outline, the embryo end tending to be the more pointed. The color is dark reddish brown. They are noticeably smaller and darker colored than those of Sudan grass and have a relatively narrower embryo (fig. 4, *d*).

APPARENT EXCEPTIONS TO THE DISTINGUISHING CHARACTERS DESCRIBED.

Conflicting conditions arise from exceptions in the manner of the fall of the seeds of Sudan grass and Johnson grass.

Occasional Sudan grass seeds have no stem at the base, but the scar usually is irregular or jagged, owing to the absence of a definite suture. Likewise, some seeds have one or both appendages unbroken, with expanded and occasionally cup-shaped apexes. The size of the seed, together with the size, form, and color of the grain, should suffice to distinguish the seed from that of Johnson grass.

Some of the seeds of Johnson grass present a short stem (fig. 5, *a*), owing to failure to separate at the articulation of the rachis and spikelet. In such cases, the distinct suture at the articulation in Johnson grass (fig. 5, *b*), evident under a good magnifier, appears to be an unfailing mark of distinction between the seeds of Johnson grass and Sudan grass. Corresponding with the occurrence of stem-bearing seeds, some of the former seeds show incomplete, broken appendages, similar to those which occur in the latter.

In the seeds of both Sudan grass and Johnson grass some individuals have a stem from one to three times as long as the seed (fig. 5, *c*). This is the portion of the branch immediately below the seed cluster, and the seed is the lowest one of the cluster. It will be observed in figure 5 and also in figure 2 that this branch is continued past the first spikelet without an evident suture (fig. 5, *d*). A partial suture for this first spikelet of the cluster does occur, however, at the base of the spikelet and is evident on the side of the axis opposite that shown in the figure, where it has the appearance shown in figure 5, *b*.

Examination of various samples of Sudan grass and Johnson grass seeds has shown the combined characters of size of seed in the hull, the presence or absence of the articulating suture, and finally the size, form, and color of the grain, including the relative size of the embryo (compare fig. 3, *e*, and fig. 4, *d*) to be conclusive points of distinction.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 407

Contribution from the Office of Public Roads and
Rural Engineering

LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER November 10, 1916

PROGRESS REPORTS OF EXPERIMENTS IN DUST PREVENTION AND ROAD PRESERVATION, 1915.

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NEW EXPERIMENTS.

The experiments begun by the Office of Public Roads and Rural Engineering during the year 1915 are all concerned with the use of bituminous materials in road construction, and include the construction of roads surfaced with bitumen and coralline rock, bitumen and sand, bituminous macadam by the penetration and mixing methods,[1] plain macadam with bituminous surface treatments, and bituminous concrete. Supplementary reports, describing the progress of experiments previously reported, follow the reports of the new experiments.

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[1] In the future publications of this office "bituminous macadam by the penetration method" will be called simply bituminous macadam, and "bituminous macadam by the mixing method" will be called bituminous concrete.

EXPERIMENTS ON MOUNT VERNON AVENUE ROAD, ALEXANDRIA COUNTY, VIRGINIA.

BITUMINOUS MACADAM (PENETRATION AND MIXING METHOD), BITUMINOUS GRAVEL CONCRETE.

This experimental project is located in general upon the Mount Vernon Avenue Road, in Alexandria County, Va. The entire project deals with the bituminous type of road construction. It begins at the Military Road, near the Arlington Cemetery, and extends on a new location to McKinley Street. Passing through McKinley Street to Columbia Pike, the road then follows a new location to the top of the hill near station 37+00, where it joins Mount Vernon Avenue. The old location of Mount Vernon Avenue is left again at station 85+00, and a new location is followed across Four Mile Run to Mount Vernon Avenue at approximately station 131+00. From there the road continues along Mount Vernon Avenue to Washington Avenue, thence through Washington Avenue and Washington Street to the city line of Alexandria. The total length of the project is 23,711 feet, or approximately 4.5 miles, and is divided into 20 experiments, as shown in Table 1. The experiments are numbered consecutively from the north end of the project toward Alexandria, and the experiments numbered 9 and 12 are identical in the construction methods employed.

The project naturally falls into three sections, according to the nature of the construction of the road base. Section I extends from the north end of the project (station −1+61) to station 153+00 at Hume, where the road crosses the tracks of the Washington-Virginia Railroad. A gravel base was laid throughout this entire section, both on the new location and on the old road, which was of earth and badly-worn gravel. Section II extends from station 153+50 to station 192+00. The base on this section is an old bituminous-macadam surface scarified and reshaped. Section III extends from station 192+00 to station 235+50, and the base is an old water-bound macadam surface, scarified and reshaped.

TABLE 1.—*Surface construction.*

	Experiment No.	Stone.	Bituminous material.	
			By penetration method.	By mixing method.
Section I	1	Sandstone	Fluxed native asphalt A	
	2	do.	Oil-asphalt X	
	3	do.		Fluxed native asphalt A.
	4	do.		Oil-asphalt X.
	5	Gneiss	Fluxed native asphalt A	
	6	do.	Oil-asphalt X	
	7	do.		Oil-asphalt X.
	8	do.		Fluxed native asphalt A.
	9	Gravel		Oil-asphalt Y.
	10	do.		Fluxed native asphalt B.
	11	do.		Refined tar.
	12	do.		Oil-asphalt Y.
Section II	13	Trap	Oil-asphalt X	
	14	do.	Fluxed native asphalt A	
	15	do.		Fluxed native asphalt A.
	16	do.		Oil-asphalt.
Section III	17	Granite	Fluxed native asphalt A	
	18	do.	Oil-asphalt X	
	19	do.		Oil-asphalt X.
	20	do.		Fluxed native asphalt A.

Work was begun under contract February 25, 1915, and the project was finished December 6, 1915. A total of 20 working days was lost, owing to unfavorable weather and other causes. Of the total cost of $65,694.45 Alexandria County paid $33,696.21.

GENERAL FEATURES OF THE PROJECT.

Equipment.—The equipment available consisted of a steam shovel, 1,000 feet of industrial-railway track and cars, a pile driver, a mechanical scarifier, a semiportable road asphalt-mixing plant, three 500-gallon portable asphalt-heating kettles, a 10-ton macadam roller, an 8-ton tandem roller, an Emerson steam pump, 2 gasoline pumps and pipe, two 5-ton motor trucks, dump-bottom wagons, drag scrapers, plows, pouring pots, and hand tools.

Excavation.—Nearly all the excavation was done by steam shovel, and material was hauled to the fills by dump wagons. The industrial railway was not used to any extent. All fills were built in layers approximately 1 foot in thickness and rolled where possible. Side-hill slopes under new fills were thoroughly plowed. Slopes in cuts were finished 1:1 and on fills 1½:1. The road was constructed 16 feet wide, with 4-foot shoulders, and the side ditches were excavated 19 inches below the grade of the road. The crown was ⅜ inch to 1 foot on all sections. Of the total of 28,575 cubic yards of necessary excavation, 27,478 cubic yards occurred on section I between stations −1+61 and 153+00.

Drainage.—Subdrainage, culverts, and catch basins were built where needed. Ungalvanized corrugated-metal pipe culverts were placed as indicated in Table 2.

TABLE 2.—*Corrugated metal culverts.*

Material.	Coppered iron, station −2+00	Ingot iron, station 9+19	Coppered iron, station 9+43	Coppered steel, station 29+00	Open-hearth steel, station 74+87	Coppered steel, station 77+99	Ingot iron, station 80+94	Open-hearth steel, station 218+96
Diameter......inches..	24	15	15	24	18	24	18	18
Analysis of metal:								
Carbon...per cent..	0.03	0.03	0.03	0.08	0.06	0.09	0.03	0.05
Sulphur..per cent..	.028	.030	.039	.046	.026	.053	.038	.029
Phosphorus, per cent..............	.0094	.009	.011	.030	.025	.0105	.012	.027
Manganese, per cent	.02	.015	.016	.37	.32	.38	.009	.31
Copper...per cent..	.16	.05	.16	.16	.016	.19	.06	.016

Concrete head walls were built for all pipe culverts and a concrete gutter was constructed on the right from station 29+00 to station 36+18 on a 4.92 per cent grade.

Four Mile Run Bridge.—It was necessary to build a new bridge over Four Mile Run at station 101+87. The design adopted for this bridge was of two 16-foot spans with 16-inch slabs. Work was commenced on the bridge March 6 and was finished June 6. The total cost was $3,332.56. Fifty-eight yellow pine piles were driven to a 20-ton theoretical bearing for the two abutments and the center pier foundations, which were built of concrete mixed in the proportions 1 : 2½ : 5. The foundations were begun 3 feet 4 inches below low water. No sheeting was used in the excavation for foundations and the pits were kept dry by the use of pumps. All concrete was mixed by hand on two large mixing platforms and a washed-gravel aggregate was used. Concrete for the slabs was of 1 : 2 : 4 mixture, and was reinforced with deformed bars. A railing was constructed of concrete with a mix of 1 part cement to 2½ parts of sharp sand.

All forms were constructed of dressed lumber and thoroughly braced. The forms for the bridge rail were oiled and other forms were kept wet during the placing of concrete. The rail was given three coats of a wash made as follows: 1 pound concentrated lye, 4 pounds alum, and 5 gallons of water, to which sufficient cement was added to make a wash that would spread with a large brush. The finished bridge has a clear width of 22 feet.

Foundation or base course.—On Section I an average interval of 60 days elapsed between the completion of excavation or rough grading and the commencement of subgrade construction and placing of gravel base. The subgrade was prepared exclusively by the use of picks and shovels, and the work was kept from three to five stations ahead of the gravel-base construction. All yielding and spongy areas were removed as rolling progressed and fresh material was supplied.

The gravel base, on this section, had an average compacted thickness of 6 inches, and was constructed of a sand-clay gravel, which occurred in three pits adjacent to the road, namely, the Zimmerman pit near station 18+00, the Garfield pit near station 95+00, and the Haney pit 1,500 feet to the right of station 116+00. The free haul of gravel was fixed at 1 mile and overhaul was practically negligible. The gravel was excavated by means of a steam shovel and distributed in rows from dump-bottom wagons. Stones over 2½ inches in size were raked out at the pit or during the spreading. The gravel contained 8.5 per cent of water and weighed approximately 3,000 pounds to a cubic yard, measured loose in a dimensioned box. Gravel from the Zimmerman and Haney pits, which were cross-sectioned, increased about 20 per cent in volume when loosened. The loose depth necessary to obtain the requisite compacted depth of 6 inches averaged 7.92 inches and the weight per station averaged 58.5 tons. The spreading was controlled by means of 6-inch blocks and lines, and the gravel was rolled with a 10-ton roller. The mechanical analyses of the gravel are shown in Table 3.

TABLE 3.—*Mechanical analyses of gravel used for foundation course.*

	Zimmerman pit.	Garfield pit.	Haney pit.
	Per cent.	*Per cent.*	*Per cent.*
Passing 2-inch, retained on 1¼-inch screen	11.2	....	....
Passing 1¼-inch, retained on 1-inch screen	4.6	1.3	....
Passing 1-inch, retained on ¾-inch screen	5.0	8.9	1.4
Passing ¾-inch, retained on ½-inch screen	9.1	11.3	15.7
Passing ½-inch, retained on ¼-inch screen	11.4	17.2	25.7
Passing ¼-inch, retained on $\frac{1}{10}$-inch screen	8.5	13.3	19.6
Passing 10-mesh, retained on 20-mesh screen	5.2	4.8	10.1
Passing 20-mesh, retained on 30-mesh screen	3.6	5.8	5.1
Passing 30-mesh, retained on 40-mesh screen	2.6	8.3	3.2
Passing 40-mesh, retained on 50-mesh screen	4.3	7.3	3.8
Passing 50-mesh, retained on 80-mesh screen	8.6	5.4	3.2
Passing 80-mesh, retained on 100-mesh screen	1.1	.5	.8
Passing 100-mesh, retained on 200-mesh screen	6.7	2.8	2.4
Passing 200-mesh screen	18.1	13.1	9.0
	100.0	100.0	100.0

The base of Section II (station 153+50 to station 192+00) was an old bituminous-macadam surface. It was scarified and reshaped without difficulty. Where excess material was found it was used to stiffen the shoulders immediately outside the new surface. Where a deficiency of material occurred, new 1½-inch broken trap rock (passing a 2½-inch screen and retained on a 1⅛-inch screen) was supplied. An average depth of about three-quarters of an inch of such stone was added to the penetration course continuously from station 153+50 to station 158+50, and from station 187+00 to station 190+50 a layer 4 inches deep, loose, was used to stiffen the base. The entire base, with added stone, was thoroughly rolled with a 10-ton roller.

The base of Section III (station 192+00 to station 235+50) was an old "water-bound" trap-rock macadam surface badly out of shape. It had apparently been repaired with limestone. It was scarified and reshaped with some difficulty, as the left edge from station 221 + 00 to station 230 + 00 was 3 inches higher than the crown. From station 201 + 00 to station 208 + 89 and from station 215 + 28 to station 219 + 00 the old macadam was entirely removed to correct the profile and a new subgrade constructed. Six inches of "1½-inch" crushed granite (passing a 2½-inch screen and retained on a 1⅛-inch screen) was then placed. It was also necessary to add such stone to weak spots in the base between station 229 + 00 and station 234 + 00. The entire base was rolled with a 10-ton macadam-roller. A gap of 639 feet occurs on this section at the viaduct over the Potomac railroad yards.

Shoulders.—Earth shoulders on Section I were constructed 4 feet wide with a slope of 1 inch to the foot, and they were finally trimmed and rolled upon completion of the work. On Section II 4-foot gravel shoulders of approximately 4 inches of compacted gravel from the Haney pit were constructed on both sides throughout the entire length. On Section III, from station 219 + 00 to station 235 + 50 similar gravel shoulders were constructed on both sides, except where a sufficient amount of material developed in the course of reshaping the old macadam with which to form a firm shoulder.

Cut-off.—Near station 2 + 50 a branch (or cut-off) was built for a distance of 230 feet along the southerly branch of the Washington-Virginia Railroad to allow traffic to pass through the new road and reach the Military Road going to Georgetown without twice crossing the railroad track. The surface of this cut-off was constructed as parts of experiments Nos. 1 and 2.

Right of way.—Approximately 10.2 acres of land were acquired by Alexandria County to provide for widening the old road and for the new right of way. All lands so acquired are marked at every point of curvature and tangency along the new right of way by means of concrete monuments.

Curves.—The reverse curve between stations 34 + 07 and 37 + 75 was widened gradually to a total width of 24 feet and suitably banked. The curve between stations 84 + 10 and 88 + 76 was widened gradually to a total width of 22 feet, and also suitably banked. The curve between stations 89 + 73 and 93 + 99 was also widened gradually to 22 feet.

Guard rail.—Wooden guard rails were constructed on Section I as follows:

From station 19+20 to station 34, left.
From station 20+26 to station 22+55, right.
From station 73+80 to station 81+64, right.
From station 74+24 to station 78+70, left.
From station 91+50, 3 panels on the right.
From station 98+70 to station 108+78, both sides.
At Hume Spring 4 panels of guard rail were erected.

The guard rail was built of red-cedar posts with two rails of yellow pine. The posts, which had been dipped in asphaltic material, were set 4 feet in the ground and sawed off 3 feet 3 inches above the surface. The 2-inch by 6-inch rails were given two coats of white lead and oil. The guard rail is set in each instance 3 feet outside the edge of the surfaced road.

Materials.—The materials used in all surface experiments were tested in the laboratories of the office and the results are given in Tables 4 to 9, inclusive.

TABLE 4.—*Physical properties of stone used in surface construction.*

Test.	Sandstone.	Gneiss.	Trap.	Granite.
Specific gravity	2.50	2.80	3.00	2.70
Weight per cubic foot ... pounds	156	175	187	168
Water absorbed per cubic foot ... pounds	.132	.28	.43	.328
Per cent of wear	4.8	3.0	2.6	3.0
French coefficient of wear	8.3	13.2	15.5	13.3
Hardness	15.5	18.8	18.3	18.7
Toughness	5	5	13	9

TABLE 5.—*Mechanical analyses of stone used in the bituminous-macadam by the penetration methods.*

	Sandstone.	Gneiss.	Trap.	Granite.
Over 2-inch screen	12.0	9.3	25.1	19.8
Passing 2-inch, retained on 1½-inch screen	55.1	59.9	47.2	57.7
Passing 1½-inch, retained on 1¼-inch screen	22.3	22.0	17.5	16.7
Passing 1¼-inch, retained on 1-inch screen	10.6	7.0	9.6	5.8
Passing 1-inch, retained on ¾-inch screen	....	1.7	.5	....
Passing ¾-inch, retained on ½-inch screen	....	....	.1	....
	100.0	99.9	100.0	100.0

TABLE 6.—*Mechanical analyses of stone and gravel used in the bituminous macadam by the mixing method, and the bituminous-concrete.*

	Sandstone.	Gneiss.	Trap.	Granite.	Gravel.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Passing 2-inch, retained on 1½-inch screen	6.4	....	22.4	1.8	....
Passing 1½-inch, retained on 1¼-inch screen	12.1	6.9	35.4	24.4	....
Passing 1¼-inch, retained on 1-inch screen	38.0	32.8	24.0	44.5	1.3
Passing 1-inch, retained on ¾-inch screen	29.5	29.5	15.0	13.5	8.9
Passing ¾-inch, retained on ½-inch screen	13.2	25.3	3.2	8.3	11.3
Passing ½-inch, retained on ¼-inch screen	.6	5.1	....	6.3	17.2
Passing ¼-inch screen	.2	.4	....	1.2	[1] 13.3
Passing 10-mesh, retained on 20-mesh screen	....	....	....	....	4.8
Passing 20-mesh, retained on 30-mesh screen	....	....	....	....	5.8
Passing 30-mesh, retained on 40-mesh screen	....	....	....	....	8.3
Passing 40-mesh, retained on 50-mesh screen	....	....	....	....	7.3
Passing 50-mesh, retained on 80-mesh screen	....	....	....	....	5.4
Passing 80-mesh, retained on 100-mesh screen	....	....	....	....	0.5
Passing 100-mesh, retained on 200-mesh screen	....	....	....	....	2.8
Passing 200-mesh screen	....	....	....	....	13.1
	100.0	100.0	100.0	100.0	100.0

[1] Retained on 10-mesh screen.

TABLE 7.—*Mechanical analyses of stone chips.*

	Sandstone.	Gneiss.	Trap.	Granite.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Passing 1¼-inch, retained on 1-inch screen				1.1
Passing 1-inch, retained on ¾-inch screen		0.5	15.8	3.8
Passing ¾-inch, retained on ½-inch screen	2.0	6.1	25.8	35.7
Passing ½-inch, retained on ¼-inch screen	25.1	27.3	32.9	47.1
Passing ¼-inch, retained on $\frac{1}{10}$-inch screen	66.0	61.5	19.4	[1] 12.3
Passing $\frac{1}{10}$-inch screen	6.7	4.6	6.1	
	99.8	100.0	100.0	100.0

[1] Passing ¼-inch screen.

TABLE 8.—*Analyses of fluxed native asphalts and oil-asphalts.*

	Fluxed native asphalts.		Oil asphalts.	
	Specification A.	Specification B.	Specification X.	Specification Y.
	Experiment numbers 1, 3, 5, 8, 14, 15, 17, 20.	Experiment number 10.	Experiment numbers 2, 4, 6, 7, 13, 16, 18, 19.	Experiment numbers 9, 12.
Specific gravity 25°/25° C	1.043	1.054	1.046	1.049
Melting point °C			50.5	54
Penetration at 25° C., 100 grams, 5 seconds	117	71	102	74
Loss, 5 hours, 163° C., 20 grams ....per cent..	2.36	2.60	0.25	0.12
Penetration of residue, as above	57	34	63	49
Per cent of total bitumen insoluble in 86° B. naphtha	23.45	24.50	26.79	28.28
Fixed carbon ....per cent..	12.48	12.66	13.92	18.75
Soluble in CS_2 (total bitumen) ....do.....	96.65	96.86	99.90	99.92
Organic matter, insoluble ....do.....	1.17	1.07	0.07	0.05
Inorganic matter, insoluble ....do.....	2.18	2.07	0.03	0.03
Total	100.00	100.00	100.00	100.00

TABLE 9.—*Analysis of refined coal tar used in bituminous gravel concrete.*

Specific gravity 25° C/25° C	1.226
Float test 50° C	2′ 58″
Soluble in CS_2 (total bitumen), per cent	87.11
Free carbon, per cent	12.80
Inorganic residue upon ignition, per cent	0.09

Distillation (Engler flask).	Character.	By volume.	By weight.
		Per cent.	*Per cent.*
Water		0.0	0.0
First light oils (to 110° C)		0.0	0.0
Second light oils (110°-170° C)		Trace.	Trace.
Heavy oils (170°-270° C.)	Solid	7.3	5.8
Heavy oils (270°-300° C.)	..do	7.1	5.7
Pitch	Hard, brittle..	85.6	88.5
		100.0	100.0

DESCRIPTION OF EXPERIMENTS.

EXPERIMENT NO. 1.—BITUMINOUS MACADAM (PENETRATION METHOD); SANDSTONE WITH FLUXED NATIVE ASPHALT A.

Location: Station −(1+61) to station 5+00.
Total length: 661 feet.
Total area: 1,202.2 square yards.[1]

The compacted gravel base described above had been under traffic for 5 months before the experimental surface was begun. The base was generally smooth and hard, but a few depressions had developed; these were filled and the surface was cleaned and rolled. Three inches of 1½-inch crushed sandstone was then spread by shovels from piles along the road. The stone had the physical properties shown in Table 4 and the mechanical analysis shown in Table 5. Uniform spreading was accomplished by the use of 3-inch cubical blocks and all irregularities were subsequently brought to a true surface. A 10-ton macadam roller was used to compact this stone layer, except that whenever available an 8-ton tandem roller was used to advantage for this purpose. The bituminous material was a fluxed native asphalt of properties shown in Table 8. It was heated in 500-gallon kettles mounted on trucks. When the asphalt had reached a temperature of 300° to 350° F. it was drawn off into 3½-gallon hand-pouring pots and a uniform penetration coat of approximately 1.5 gallons to the square yard applied. While the oil was still hot clean stone chips were uniformly spread to fill the superficial voids and immediately rolled. The chips were broomed to an even distribution and excess chips removed as the rolling progressed.

A seal coat of hot asphalt approximately one-half gallon to the square yard was then similarily applied. Chips were then applied in such quantity as to leave a slight excess, and the surface was again rolled. The mechanical analysis of the sandstone chips is shown in Table 7. All the sandstone chips broke up immediately under rolling and traffic.

EXPERIMENT NO. 2.—BITUMINOUS MACADAM (PENETRATION METHOD); SANDSTONE WITH OIL-ASPHALT X.

Location: Station 5+00 to station 18+00.
Total length: 1,300 feet.
Total area: 2,599.7 square yards.[2]

The construction of this experiment was exactly as described for Experiment No. 1, except that the asphaltic material was an oil asphalt described in Table 8. A subdrain was constructed on the right from station 12+50 to station 18+25. It was built with 6-inch bell and spigot joint tile pipe laid 4 feet below the finished grade, and was covered to a depth of 12 inches with broken stone, on top of which was placed a 10-inch course of cobble stones. The drain was under the gutter line and was completed with a layer of earth.

---

[1] Includes 27 square yards at end of cut-off.

[2] Includes 289 square yards at beginning of cut-off.

EXPERIMENT NO. 3.—BITUMINOUS MACADAM (MIXING METHOD); SANDSTONE WITH FLUXED NATIVE ASPHALT A.

Location: Station 18+00 to station 28+10.
Length: 1,010 feet.
Total area: 1,867.8 square yards.

The compacted gravel base for this experiment had been under traffic about 4 months before the surface was laid. A thin layer of dust had developed and in a few instances the surface of the base was not true to section. The section was revised by hand picking, the addition of gravel to the hollows, and rolling. In general the base presented a smooth, hard appearance and was thoroughly swept with ordinary house brooms directly in advance of the placing of the bituminous macadam. The stone was $\frac{3}{4}$-inch sandstone with physical properties and mechanical analysis as shown in Tables 4 and 6, respectively. It was mixed with the hot bituminous material in the proportions of 38 pounds of asphalt to 600 pounds of stone in a semiportable mixing plant near station 95+00. The resulting percentage of asphalt to total weight of the mix was 5.95 per cent. The mix was hauled in dump-bottom wagons to the point of placing and dumped on spreading boards. It was spread at an average temperature of about 300° F. by shovels and rakes on the cleaned gravel base to produce a compacted depth of 2 inches.

The mixing plant raised the aggregate by means of a bucket-belt from a feeding pit into a heating cylinder, where it was heated. The heated aggregate was then elevated to a storage bin, from which it was run into a weighing hopper and thence into the mixing box. The asphalt was heated in two kettles, each of 1,000 gallons capacity, and dipped by ladles into a weighing kettle from which the hot material could be poured into the mixing box. The pouring began as the chute from the aggregate weighing hopper opened, while the blades of the mixer revolved continuously. A full minute was the minimum time of mixing, and the mixed material was then allowed to drop into the dump wagon.

The resulting mix was very satisfactory, as all the particles of aggregate were thoroughly coated. The temperature of the stone in the weighing hopper was constantly tested by the hand, and the temperature was checked at intervals by a thermometer, as was also the temperature of the asphalt. No separation of the mix occurred during the haul, and it arrived on the work almost without exception at a temperature above 220° F.

Immediately after the mixture was cooled sufficiently to avoid "waving," it was rolled with an 8-ton tandem roller. A seal coat of approximately one-half gallon of fluxed native asphalt A to the square yard was then applied by hand pouring pots, as described in experiments Nos. 1 and 2. Sandstone chips approximately free from dust, as indicated in the mechanical analysis of Table 7, were then spread uniformly in sufficient quantity to fill the superficial voids, and broomed with rattan brooms while the roller worked. A slight excess of chips was applied, which soon broke up into fine particles under traffic.

EXPERIMENT NO. 4.—BITUMINOUS MACADAM (MIXING METHOD); SANDSTONE WITH OIL-ASPHALT X.

Location: Station 28+10 to station 38+10.
Total length: 1,000 feet.
Total area: 1,924 square yards.

This experiment was exactly similar to experiment No. 3, except that oil-asphalt X of properties shown in Table 8 was used instead of fluxed native asphalt. The maximum grade on this section is 4.92 per cent.

EXPERIMENT NO. 5.—BITUMINOUS MACADAM (PENETRATION METHOD); GNEISS WITH FLUXED NATIVE ASPHALT A.

Location: Station 38+10 to station 50+45.
Total length: 1,235 feet.
Total area: 2,196.6 square yards.

This experiment was exactly similar to experiment No. 1, except that "1½-inch" gneiss was used instead of sandstone. The mechanical analysis of the crushed gneiss is shown in Table 5 and the physical properties of the stone in Table 4. The mechanical analysis of the chips used is shown in Table 7. The chips broke up into fine particles under traffic.

EXPERIMENT NO. 6.—BITUMINOUS MACADAM (PENETRATION METHOD); GNEISS WITH OIL-ASPHALT X.

Location: Station 50+45 to station 58+45.
Total length: 800 feet.
Total area: 1,422.2 square yards.

This experiment was exactly similar to experiment No. 5, except that oil-asphalt X was used instead of fluxed native asphalt.

EXPERIMENT NO. 7.—BITUMINOUS MACADAM (MIXING METHOD); GNEISS WITH OIL-ASPHALT X.

Location: Station 58+45 to station 71+78.
Length: 1,333 feet.
Total area: 2,369.8 square yards.

The crushed gneiss used in the bituminous mixture had the physical properties shown in Table 4 and of mechanical analysis shown in Table 6. The mechanical analysis of the gneiss chips used on this experiment is shown in Table 7. The experiment was otherwise exactly similar to experiment No. 4.

EXPERIMENT NO. 8.—BITUMINOUS MACADAM (MIXING METHOD); GNEISS WITH FLUXED NATIVE ASPHALT A.

Location: Station 71+78 to station 78+65.
Total length: 587 feet.
Total area: 1,221.3 square yards.

This experiment is exactly similar to experiment No. 7, except that fluxed native asphalt A, with properties as shown in Table 8, was used instead of the oil-asphalt.

EXPERIMENT NO. 9.—BITUMINOUS GRAVEL CONCRETE, PIT-RUN GRAVEL, WITH OIL-ASPHALT Y.

Location: Station 78+65 to station 89+50.
Total length: 1,095 feet.
Total area: 2,152.1 square yards.

TABLE 10.—*Typical analyses of oil-asphalt gravel mixtures used in experiment No. 9.*

	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Bitumen soluble in CS^2	6.4	6.9	7.5
Mechanical analysis of aggregate:			
Passing 1-inch screen, retained on ¾-inch screen	5.7	6.7	4.4
Passing ¾-inch screen, retained on ½-inch screen	16.9	11.4	12.8
Passing ½-inch screen, retained on ¼-inch screen	17.1	19.9	18.6
Passing ¼-inch screen, retained on 10-mesh sieve	12.6	12.2	13.9
Passing 10-mesh sieve, retained on 20-mesh sieve	8.5	6.5	6.5
Passing 20-mesh sieve, retained on 30-mesh sieve	10.3	10.5	8.6
Passing 30-mesh sieve, retained on 40-mesh sieve	11.0	11.4	11.1
Passing 40-mesh sieve, retained on 50-mesh sieve	6.5	8.9	7.2
Passing 50-mesh sieve, retained on 80-mesh sieve	6.2	6.1	6.4
Passing 80-mesh sieve, retained on 100-mesh sieve	0.8	0.8	1.0
Passing 100-mesh sieve, retained on 200-mesh sieve	2.2	2.8	3.4
Passing 200-mesh sieve	2.2	2.8	6.1
Total	100.0	100.0	100.0

The gravel base for this experiment had been open to travel several weeks and was hard and smooth when surfacing commenced. Wherever small depressions or irregularities had developed they were corrected by hand picking and the application of new gravel, which was thoroughly rolled.

The gravel used for the aggregate in the bituminous concrete was a uniform dense gravel containing much fine material, as shown by the mechanical analysis in Table 6. It was taken exclusively from the Garfield pit, where it was excavated by steam shovel and then hauled 1,000 feet to a storage pile near station 95+00. It was fed into the mixer through a 2-inch screen.

When the gravel was heated the clay formed a fine powder or dust and much of it blew away in dropping the material from the storage bin into the weighing hopper and from there into the mixing box.

The oil asphalt was mixed with the heated gravel in the proportions of 36.5 pounds to 500 pounds of gravel. The resulting percentage of bitumen by weight was approximately 6.8. Typical analyses of the mixture are given in Table 10.

The method of placing the bituminous gravel concrete was exactly as described for the bituminous mixed macadam experiments with stone aggregate. The depth of spreading was approximately 3 inches loose, and the compacted thickness was approximately 2 inches. The mix was allowed to set from 1 to 2 hours before rolling, to avoid a wavy surface.

The rolled surface before sealing presented a smooth, dense appearance, except for occasional small superficial pits. A seal coat of the same asphaltic material used in the mix was applied at a temperature of about 300° F. at the rate of one-half gallon to the square yard. Clean pea gravel was at once spread uniformly and the surface rolled. The maximum grade for this section is 5.24 per cent.

EXPERIMENT NO. 10.—BITUMINOUS GRAVEL CONCRETE. PIT-RUN GRAVEL WITH FLUXED NATIVE ASPHALT B.

Location: Station 89+50 to station 118+10.
Total length: 2,860 feet.
Total area: 5,445.2 square yards.

This experiment was constructed exactly as experiment No. 9, except that fluxed native asphalt B was used instead of oil asphalt. Typical analyses of the mixture are given in Table 11. The maximum grade is 4.08 per cent.

EXPERIMENT NO. 11.—BITUMINOUS GRAVEL CONCRETE. PIT-RUN GRAVEL WITH REFINED TAR.

Location: Station 118+10 to station 126+95.
Total length: 885 feet.
Total area: 1,573.3 square yards.

This experiment was constructed exactly as experiments Nos. 9 and 10, except that a refined tar was used throughout. The analysis of the tar is given in Table 9. The proportions of the mix were 43 pounds of tar to 500 pounds of gravel, which resulted in a percentage of 7.92 of tar to total weight of mixture. Typical analyses of the mixture are presented in Table 12.

TABLE 11.—*Analyses of typical samples of fluxed native asphalt gravel mix used in experiment No. 10.*

	I.	II.	III.
	Per cent.	*Per cent.*	*Per cent.*
Bitumen soluble in CS^2	6.39	7.11	7.26
Mineral aggregate:			
Passing 1¼-inch screen, retained on 1-inch screen		3.3	
Passing 1-inch screen, retained on ¾-inch screen	8.9	2.7	5.2
Passing ¾-inch screen, retained on ½-inch screen	7.5	12.7	9.9
Passing ½-inch screen, retained on ¼-inch screen	18.0	18.7	19.4
Passing ¼-inch screen, retained on 10-mesh sieve	13.4	12.1	14.5
Passing 10-mesh sieve, retained on 20-mesh sieve	7.0	5.9	7.3
Passing 20-mesh sieve, retained on 30-mesh sieve	8.8	8.0	11.5
Passing 30-mesh sieve, retained on 40-mesh sieve	11.1	11.2	13.4
Passing 40-mesh sieve, retained on 50-mesh sieve	9.3	7.4	7.3
Passing 50-mesh sieve, retained on 80-mesh sieve	6.3	7.2	5.8
Passing 80-mesh sieve, retained on 100-mesh sieve	1.8	.8	.8
Passing 100-mesh sieve, retained on 200-mesh sieve	3.2	3.3	2.1
Passing 200-mesh sieve	4.7	6.7	2.8
Total	100.0	100.0	100.0

TABLE 12.—*Typical analyses of tar-gravel mixtures used in experiment No. 11.*

	I.	II.
	Per cent.	*Per cent.*
Bitumen soluble in CS^2	7.1	7.6
Mineral aggregate:		
Passing 2-inch screen, retained on 1½-inch screen		5.8
Passing 1½-inch screen, retained on 1¼-inch screen		0.0
Passing 1¼-inch screen, retained on 1-inch screen		4.0
Passing 1-inch screen, retained on ¾-inch screen	13.3	4.7
Passing ¾-inch screen, retained on ½-inch screen	11.4	9.7
Passing ½-inch screen, retained on ¼-inch screen	11.7	15.5
Passing ¼-inch screen, retained on 10-mesh sieve	13.1	12.5
Passing 10-mesh sieve, retained on 20-mesh sieve	8.5	7.2
Passing 20-mesh sieve, retained on 30-mesh sieve	9.6	9.6
Passing 30-mesh sieve, retained on 40-mesh sieve	11.0	10.6
Passing 40-mesh sieve, retained on 50-mesh sieve	8.5	8.1
Passing 50-mesh sieve, retained on 80-mesh sieve	6.1	5.9
Passing 80-mesh sieve, retained on 100-mesh sieve	1.1	.6
Passing 100-mesh sieve, retained on 200-mesh sieve	3.0	3.0
Passing 200-mesh sieve	2.7	2.8
Total	100.0	100.0

EXPERIMENT NO. 12.—BITUMINOUS GRAVEL CONCRETE. PIT-RUN GRAVEL WITH OIL-ASPHALT Y.

Location: Station 126+95 to station 153+00.
Total length: 2,605 feet.
Total area: 4,711.1 square yards.

This experiment was exactly the same as experiment No. 9.

EXPERIMENT NO. 13.—BITUMINOUS MACADAM (PENETRATION METHOD). TRAP ROCK WITH OIL-ASPHALT X.

Location: Station 153+50 to station 163+00.
Length: 950 feet.
Total area: 1,688.9 square yards.

The base for the surface experiment was an old bituminous-macadam road, which was scarified, reshaped, and rolled with a 10-ton roller. The old road crown varied from 2 to 6 inches, but was reshaped without difficulty. From stations 153+53 to 158+50 an extra depth of about three-fourths of an inch of trap was spread, so that the total depth of stone averaged nearly 4 inches loose. The "1½-inch" crushed trap used was of physical properties and mechanical analysis shown in Tables 4 and 5, respectively. The oil-asphalt analysis is given in Table 8. The mechanical analysis of the trap screenings or chips is shown in Table 7.

The experiment was constructed otherwise as previously described for the penetration macadam experiments with sandstone and gneiss.

EXPERIMENT NO. 14.—BITUMINOUS MACADAM (PENETRATION METHOD). TRAP ROCK WITH FLUXED NATIVE ASPHALT A.

Location: Station 163+00 to station 173+00.
Length: 1,000 feet.
Total area: 1,777.8 square yards.

This experiment was constructed exactly like experiment No. 13, except that fluxed native asphalt was used instead of oil asphalt, and that the extra depth of stone for the base was not required.

EXPERIMENT NO. 15.—BITUMINOUS MACADAM (MIXING METHOD). TRAP ROCK WITH FLUXED NATIVE ASPHALT A.

Location: Station 173+00 to station 182+80.
Total length: 980 feet.
Total area: 1,742.2 square feet.

This experiment was constructed on the same kind of base as experiments Nos. 13 and 14. Trap rock of physical properties and mechanical analysis shown in Tables 4 and 6, respectively, and trap chips of mechanical analysis shown in Table 7 were used. Otherwise the construction was similar to that of experiments Nos. 3 and 8. The mixing plant was located near station 215+00.

EXPERIMENT NO. 16.—BITUMINOUS MACADAM (MIXING METHOD). TRAP ROCK WITH OIL-ASPHALT X.

Location: Station 182+80 to station 192+00.
Length: 920 feet.
Total area: 1,621.4 square yards.

This experiment was constructed on the same kind of base as experiments Nos. 13, 14, and 15. From station 187+00 to station 190+50, 84.5 tons of "1½-inch" trap was added to the foundation in a uniform layer and rolled with a 10-ton roller. This spread stone was unfortunately traveled over for nearly 30 days and it became somewhat rounded before the surface was laid. It was necessary to replace the old pipe culvert at station 189+64, and bad weather during the progress of the work caused considerable settlement of the adjacent fill before the new culvert was completed.

The experiment was exactly like experiment No. 15, except that oil-asphalt was used instead of fluxed native asphalt. Mixing for the area between stations 182+80 and 192+00 was done at position

No. 2 of the mixing plant at station 95+00, and some bituminous material was lost in the long haul. The analysis of the fluxed native asphalt is shown in Table 8.

EXPERIMENT NO. 17.—BITUMINOUS MACADAM (PENETRATION METHOD). GRANITE WITH FLUXED NATIVE ASPHALT A.

Location: Station 192+00 to station 200+00.
Total length: 800 feet.
Total area: 1,422.2 square yards.

The base of this section consisted primarily of an old water-bound trap macadam road, which was scarified and reshaped. It was necessary to widen the old road an average of 2 feet. The added width of base was of "1½-inch" granite, which was also used to supplement a few weak spots in the old macadam base. The entire base was thoroughly rolled and compacted by a 10-ton roller. No binder was used.

The method of laying the surface in this experiment was exactly similar to that of experiment No. 13. The materials used, however, were fluxed native asphalt A and "1½-inch" granite. The properties of the asphalt are shown in Table 8, and the physical properties and mechanical analysis of the granite are shown in Tables 4 and 5, respectively. The mechanical analysis of the chips used is shown in Table 7.

EXPERIMENT NO. 18.—BITUMINOUS MACADAM (PENETRATION METHOD). GRANITE WITH OIL-ASPHALT X.

Location: Station 200+00 to station 208+89.
Total length: 889 feet.
Total area: 1,580.4 square yards.

The base of this experiment from stations 200+00 to 201+00 was similar to that described for experiment No. 17. From stations 201+00 to 208+89 the old macadam was entirely removed to revise the grade, and a base of "1½-inch" granite was laid to a loose depth of 6 inches and thoroughly compacted by a 10-ton macadam roller without the addition of any binder.

In other particulars this experiment was exactly similar to experiment No. 17, except that an oil-asphalt X was used with properties as shown in Table 8, instead of fluxed native asphalt.

EXPERIMENT NO. 19.—BITUMINOUS MACADAM (MIXING METHOD). GRANITE WITH OIL-ASPHALT X.

Location: Station 215+28 to station 225+10.
Total length: 982 feet.
Total area: 1,728 square yards.

The base of this experiment was an old water-bound trap-rock macadam road, rather badly out of shape. It was scarified and reshaped from station 219+00 to the end of the experiment. From stations

215+28 to 219+00 it was necessary to remove entirely the old macadam base to correct the profile, and a new base was built of "1½-inch" granite spread to a loose depth of 6 inches and rolled with a 10-ton roller until compacted, without the addition of any binder.

The surface was exactly similar to that in experiment No. 16, except that the stone was granite, with physical properties and mechanical analyses as shown in Tables 4 and 6, respectively. The mechanical analyses of the chips used are shown in Table No. 7. The percentage of the weight of asphalt to the total weight of asphalt and stone was 6.73. The mixing was done near station 215+00.

EXPERIMENT No. 20.—BITUMINOUS MACADAM (MIXING METHOD). GRANITE WITH FLUXED NATIVE ASPHALT A.

Location: Station 225+10 to station 235+50.
Total length: 1,040 feet.
Total area: 1,866.7 square yards.

The base of this experiment was an old trap-rock water-bound macadam road, which was scarified and reshaped. Considerable extra stone ("1½-inch" granite) was added from stations 229+00 to 234+00 to supplement weak places in the old macadam.

The surface was laid exactly as in experiment No. 19, except that fluxed native asphalt of the analysis shown in Table 8 was used instead of oil-asphalt.

SUMMARY OF COST DATA FOR ENTIRE PROJECT.

The cost data for the experiments described above are presented in the tables which follow, Nos. 13 to 23.

TABLE 13.—*Cost data for subgrade.*

[Subgrade, stations −(1+61) to 235+50.]

Items.	Clearing and grubbing.	Excavation.	Shaping.	Scarifying and reshaping.	Rolling.	Subgrade, complete.
	Acres.	*Cubic yards.*	*Square yds.*	*Square yds.*	*Square yds.*	*Square yds.*
Quantity	5.0000	28,575	45,835	11,378	57,213	[1] 42,111
Labor	$125.57	$8,237.71	$3,035.83	$348.17	$72.74	$11,820.02
Materials	....	287.05	....	6.80	30.55	324.40
Total	125.57	8,524.76	3,035.83	354.97	103.29	12,144.42
	Acre.	*Cubic yard.*	*Square yard.*	*Square yard.*	*Square yard.*	*Square yard.*
Unit cost	$25.114	$0.2983	$0.0662	$0.0312	$0.0018	$0.2884
Per cent of total cost	.22	15.24	5.42	.64	.19	21.71

[1] Does not include shoulders.

TABLE 14.—*Cost data for gravel shoulders.*

[Gravel shoulders, stations −(1+61) to 235+50.]

Items.	Gravel in pit.	Loosen and load.	Haul.	Spread.	Rolling.	Gravel shoulders complete.
	Tons.	*Tons.*	*Tons.*	*Square yds.*	*Square yds.*	*Square yds.*
Quantity	984.59			5,220	5,220	5,220
Labor		$85.23	$293.07	$111.17	$7.50	$496.97
Materials	$65.64	5.10			3.15	73.89
Total	65.64	90.33	293.07	111.17	10.65	570.86
Cost per square yard	$0.0126	$0.0173	$0.0561	$0.0213	$0.0020	$0.1093
Per cent of total cost	.12	.17	.52	.20	.02	1.02

TABLE 15.—*Cost data for drainage structures.*

[Drainage, stations −(1+61) to 235+50.]

Items.	Concrete bridge.	Concrete culverts.	Pipe culverts.	French drain.	Cobble drain.	Open drain.	Concrete gutter.	Drainage system.
	Cu. yds.	*Cu. yds.*	*Linear ft.*	*Linear ft.*	*Linear ft.*	*Linear ft.*	*Cu. yds.*[1]	
Quantity	219.22	127.87	568	705	162	1,850	46.54	
Labor	$1,453.12	$738.16	$477.74	$508.39	$69.99	$116.42	$138.60	$3,502.42
Materials	1,879.44	897.95	684.08	217.73		22.60	173.27	3,875.07
Total	3,332.56	1,636.11	1,161.82	726.12	69.99	139.02	311.87	7,377.49
Per cent of total cost.	5.96	2.92	2.07	1.30	.12	.25	.56	13.18

[1] 718 linear feet.

TABLE 16.—*Cost data for incidentals.*

[Incidentals, stations −(1+61) to 235+50.]

Items.	Superintendence.	Equipment.	Extra work.	Guard rail.	Waste bitumen.	Miscellaneous.	Boundary stones.	Total.
Labor	$2,544.91		$709.84	$440.74	$16.49	$396.65	$42.16	$4,150.79
Materials			158.72	517.35	573.19	32.55	17.85	1,299.66
Interest, rental, depreciation		$3,120.71						3,120.71
Total	2,544.91	3,120.71	868.56	958.09	589.68	429.20	60.01	8,571.16
Per cent of total cost.	4.55	5.58	1.55	1.71	1.05	.76	.11	15.31

TABLE 17.—*Cost data for foundation course.*

[Foundation course, stations −(1+61) to 235+50.]

Items.	Material.	Loosen and load.	Haul.	Spread.	Rolling.	Foundation complete.
	Tons.	*Tons.*	*Tons.*	*Sq. yds.*	*Sq. yds.*	*Sq. yds.*
Quantity	9,736.68	1,675.32	1,675.32	41,886.90	41,886.90	41,886.90
Labor		$807.94	$1,694.02	$756.01	$134.75	$3,392.72
Materials	$1,573.15	41.65			56.51	1,671.31
Total	1,573.15	849.59	1,694.02	756.01	191.26	5,064.03
Cost per square yard	0.0376	0.0203	0.0404	0.0180	0.0046	0.1209
Per cent of total cost	2.81	1.52	3.03	1.35	.35	9.06

TABLE 18.—*Cost data for surfacing.*

[Surfacing, stations −(1+61) to 235 +50.][1]

Items.	Stone on work.	Spreading stone.	Bitumen on work.	Application of bitumen.	Rolling.	Surfacing, complete.
	Tons.	*Tons.*	*Gallons.*	*Sq. yds.*	*Sq. yds.*	*Sq. yds.*
Quantity	5,735.68	5,735.68	90,557	42,111.90	42,111.90	42,111.90
Labor	$2,139.58	$944.82	$209.26	$3,588.30	$213.34	$7,095.30
Materials	6,601.98	....	8,274.42	180.32	89.25	15,145.97
Total	8,741.56	944.82	8,483.68	3,768.62	302.59	22,241.27
	Ton.	*Ton.*	*Gallon.*	*Sq. yd.*	*Sq. yd.*	*Sq. yd.*
Unit cost	$1.5240	$0.1647	$0.0937	$0.0895	$0.0072	$0.5281
Per cent of total cost	15.62	1.69	15.16	6.73	.54	39.74

[1] Average over all experiments.

TABLE 19.—*Materials and cost data per square yard for bituminous macadam by the penetration method.*

Experiment No.	Station.	Description.				Quantity of material.		
		Stone.	Bitumen.	Length of section.	Area of section.	Stone.	Chips.	Bitumen.
				Feet.	*Sq. yards.*	*Tons.*	*Tons.*	*Gallons.*
1	−(1+61) to 5+00	Sandstone	Asphalt A	661	1,202.22	0.134	0.022	2.17
2	5+00 to 18+00	...do	Asphalt X	1,300	2,599.67	.134	.022	2.04
5	38+10 to 50+45	Gneiss	Asphalt A	1,235	2,195.56	.098	.018	2.03
6	50+45 to 58+45	...do	Asphalt X	800	1,422.22	.098	.018	2.12
13	153+00 to 163+00	Trap	.....do	950	1,688.88	.122	.033	2.03
14	163+00 to 173+00	...do	Asphalt A	1,000	1,777.78	.122	.033	2.02
17	192+00 to 200+00	Granite	.....do	800	1,422.22	.117	.025	2.12
18	200+00 to 208+89	...do	Asphalt X	889	1,580.45	.117	.025	1.92

Experiment No.	Station.	Cost per square yard (cents).							
		Stone on siding.	Unloading stone.	Hauling stone.	Spreading stone.	Chips on siding.	Unloading chips.	Hauling chips.	Spreading chips.
1	−(1+61) to 5+00	30.66	....	8.61	1.45	5.11	....	1.44	1.55
2	5+00 to 18+00	30.65	....	8.60	1.43	5.11	....	1.43	1.57
5	38+10 to 50+45	11.78	....	1.89	.72	2.10	....	.34	1.84
6	50+45 to 58+45	11.78	....	1.90	.75	2.10	....	.34	1.89
13	153+00 to 163+00	15.25	2.21	3.05	.89	6.14	0.60	.83	1.77
14	163+00 to 173+00	15.24	2.21	3.05	.89	6.14	.60	.83	1.78
17	192+00 to 200+00	16.75	1.89	4.10	1.91	3.55	.40	.87	1.24
18	200+00 to 208+89	16.75	1.90	4.11	1.91	3.56	.40	.87	1.25

Experiment No.	Station.	Cost per square yard (cents).						
		Bitumen on siding.	Hauling bitumen.	Loading and heating bitumen.	Applying bitumen.	Rolling penetration stone.	Rolling penetration and seal.	Total cost.
1	−(1+61) to 5+00	26.71	.50	1.70	1.78	.21	.41	80.13
2	5+00 to 18+00	13.27	.47	1.59	1.67	.22	.42	66.43
5	38+10 to 50+45	24.95	.47	1.26	1.85	.12	.42	47.74
6	50+45 to 58+45	13.78	.49	1.32	1.93	.13	.44	36.85
13	153+00 to 163+00	13.16	.47	1.29	1.50	.56	.69	48.41
14	163+00 to 173+00	25.51	.47	1.39	1.62	.56	.69	58.98
17	192+00 to 200+00	26.93	.49	1.71	2.02	.50	.68	63.04
18	200+00 to 208+89	12.52	.44	1.55	1.84	.50	.69	48.29

TABLE 20.—*Total materials and costs for bituminous macadam by the penetration method.*

Experiment No.	Station.	Description.				Quantity of material per square yard.		
		Stone.	Bitumen.	Length of section.	Area of section.	Stone.	Chips.	Bitumen.
				Feet.	*Sq. yds.*	*Tons.*	*Tons.*	*Gallons.*
1	−(1+61) to 5+00	Sandstone	Asphalt A..	661	[1] 2,102.22	160.94	26.82	2,610
2	5+00 to 18+00	...do......	Asphalt X..	1,300	[2] 2,599.67	348.00	58.00	5,310
5	38+10 to 50+45	Gneiss....	Asphalt A..	1,235	2,195.56	214.39	38.28	4,455
6	50+45 to 58+45	....do.....	Asphalt X..	800	1,422.22	138.82	24.79	3,015
13	153+00 to 163+00	Trap......	...do........	950	1,688.88	206.07	56.02	3,420
14	163+00 to 173+00	...do......	Asphalt A .	1,000	1,777.78	216.86	59.18	3,600
17	192+00 to 200+00	Granite...	.....do......	800	1,422.22	166.53	35.27	3,015
18	200+00 to 208+89	...do......	Asphalt X..	889	1,580.45	185.02	39.28	3,044
	Total.......	....	....	7,635	13,889.00	1,636.63	337.64	28,469

Experiment No.	Station.	Total costs.							
		Stone on siding.	Unloading stone.	Hauling stone.	Spreading stone.	Chips on siding.	Unloading chips.	Hauling chips.	Spreading chips.
1	−(1+61)to 5+00	$368.55	....	$103.42	$17.46	$61.42	....	$17.34	$18.73
2	5+00 to 18+00	796.92	....	223.53	37.09	132.82	....	37.26	40.72
5	38+10 to 50+45	258.58	....	41.65	15.71	46.06	....	7.41	40.41
6	50+45 to 58+45	167.43	....	27.07	10.69	29.83	....	4.89	26.94
13	153+00 to 163+00	257.59	$37.32	51.49	15.04	103.64	$10.14	13.99	29.88
14	163+00 to 173+00	271.07	39.27	54.17	15.84	109.48	10.71	14.79	31.59
17	192+00 to 200+00	238.14	26.92	58.24	27.21	50.44	5.69	12.32	17.67
18	200+00 to 208+89	264.58	30.02	64.96	30.16	56.17	6.39	13.81	19.81
	Total...........	2,622.86	133.53	624.53	169.20	589.86	32.93	121.81	225.75

Experiment No.	Station.	Total costs.						
		Bitumen on siding.	Hauling bitumen.	Loading and heating bitumen.	Applying bitumen.	Rolling penetration, stone.	Rolling penetration and seal.	Total cost.
1	−(1+61)to 5+00	$321.03	$6.03	$20.41	$21.41	$2.52	$4.89	$963.21
2	5+00 to 18+00	345.15	12.27	41.43	43.48	5.64	10.88	1,727.19
5	38+10 to 50+45	547.97	10.29	27.74	40.53	2.67	9.28	1,048.30
6	50+45 to 58+45	195.97	6.97	18.81	27.47	1.78	6.19	524.04
13	153+00 to 163+00	222.30	7.90	21.81	25.35	9.51	11.67	817.63
14	163+00 to 173+00	453.60	8.32	24.70	28.75	10.01	12.30	1,084.60
17	192+00 to 200+00	382.91	6.97	24.25	28.79	7.07	9.74	896.36
18	200+00 to 208+89	197.86	7.03	24.43	29.01	7.84	10.85	762.92
	Total.............	2,666.79	65.78	203.58	244.79	47.04	75.80	7,824.25

[1] Includes 27 square yards end of cut-off north.

[2] Includes 289 square yards end of cut-off south.

TABLE 21.—*Materials and cost data per square yard for bituminous macadam by the mixing method, and bituminous concrete surfaces.*

Experiment No.	Station.	Description.				Quantity of material per square yard.			
		Stone.	Bitumen.	Length of section.	Area of section.	Stone.	Chips.	Binder bitumen.	Seal bitumen.
				Feet.	*Sq. yds.*	*Tons.*	*Tons.*	*Gallons.*	*Gallons.*
3	18+00 to 28+10	Sandstone	Asphalt A..	1,010	1,867.78	0.143	0.020	1.66	0.48
4	28+10 to 38+10	...do.......	Asphalt X..	1,000	1,924.00	.137	.020	1.59	.51
7	58+45 to 71+78	Gneiss....	.....do.......	1,333	2,369.78	.108	.013	1.59	.51
8	71+78 to 78+65	...do.......	Asphalt A...	687	1,221.33	.108	.013	1.58	.52
9	78+65 to 89+50	Gravel....	Asphalt Y...	1,085	6,863.22	.140	.007	1.96	.50
12	126+95 to 153+00			2,605					
10	89+50 to 118+10	...do.......	Asphalt B...	2,860	2,445.22	.114	.007	1.54	.48
11	118+10 to 126+95	...do.......	Tar.........	885	1,573.34	.130	.007	1.79	.50
15	173+00 to 182+80	Trap......	Asphalt A...	980	1,742.22	.118	.023	1.57	.50
16	182+80 to 192+00	...do.......	Asphalt X..	920	1,621.34	.119	.024	1.54	.46
19	215+28 to 225+10	Granite...	.....do.......	982	1,728.00	.085	.014	1.75	.56
20	225+10 to 235+50	...do.......	Asphalt A...	1,040	1,866.67	.085	.014	1.74	.51

Experiment No.	Station.	Cost per square yard (cents).								
		Stone on siding.	Unloading stone.	Hauling stone.	Chips on siding.	Unloading chips.	Hauling chips.	Binder bitumen on siding.	Hauling binder bitumen.	Seal bitumen on siding.
3	18+00 to 28+10	32.85	....	9.18	4.65	....	1.30	20.44	0.38	5.90
4	28+10 to 38+10	31.29	....	8.78	4.55	....	1.27	10.32	.37	3.31
7	58+45 to 71+78	13.54	....	2.92	1.64	....	.36	10.31	.36	3.31
8	71+78 to 78+65	13.55	....	2.92	1.64	....	.36	19.43	.37	6.40
9	78+65 to 89+50	.94	1.06	2.23	.76	....	.74	11.56	.45	2.95
12	126+95 to 153+00									
10	89+50 to 118+10	.76	.86	1.80	.76	....	.73	19.56	.36	6.10
11	118+10 to 126+95	.87	.98	2.05	.75	....	.75	17.92	.41	5.00
15	173+00 to 182+80	17.08	1.96	1.22	4.32	0.39	.24	19.98	.36	6.35
16	182+80 to 192+00	17.19	1.98	1.23	4.36	.39	.24	10.02	.36	2.99
19	215+28 to 225+10	12.15	1.41	....	1.98	.23	.31	11.34	.40	3.64
20	225+10 to 235+50	12.15	1.41	....	1.98	.23	.31	22.10	.40	6.48

Experiment No.	Station.	Cost per square yard (cents).								
		Hauling seal bitumen.	Heating and mixing.	Hauling mix.	Spreading mix.	Rolling mix.	Applying seal bitumen.	Spreading chips.	Rolling seal.	Total cost.
3	18+00 to 28+10	0.11	6.38	5.26	1.19	0.24	0.55	0.52	0.08	88.98
4	28+10 to 38+10	.12	6.33	5.19	1.17	.32	.60	.54	.11	74.27
7	58+45 to 71+78	.12	6.77	3.02	1.02	.34	.91	.80	.15	45.57
8	71+78 to 78+65	.12	6.77	3.02	1.02	.33	.94	.80	.14	57.81
9	78+65 to 89+50	.12	7.02	2.71	1.17	.39	.84	.46	.14	33.54
12	126+95 to 153+00									
10	89+50 to 118+10	.11	7.02	2.71	1.17	.39	.82	.46	.13	43.74
11	118+10 to 126+95	.12	7.03	2.72	1.17	.40	.86	.45	.14	41.62
15	173+00 to 182+80	.12	6.57	4.50	1.12	.38	.50	.57	.11	65.77
16	182+80 to 192+00	.11	6.59	4.53	1.12	.38	.50	.57	.10	52.66
19	215+28 to 225+10	.13	10.05	5.51	2.98	1.09	1.67	.83	.54	54.26
20	225+10 to 235+50	.12	10.01	5.48	2.96	1.09	1.64	.83	.54	67.73

TABLE 22.—*Total materials and costs for bituminous macadam by the mixing method and bituminous concrete surfaces.*

Experiment No.	Station.	Description.				Quantity of material per square yard.			
		Stone.	Bitumen.	Length of section.	Area of section.	Stone.	Chips.	Binder bitumen.	Seal bitumen.
				Feet.	*Sq. yds.*	*Tons.*	*Tons.*	*Galls.*	*Galls.*
3	18+00 to 28+10	Sandstone	Asphalt A..	1,010	1,867.78	267.54	37.56	3,104	896
4	28+10 to 38+10	...do......	Asphalt X.	1,000	1,924.00	262.92	38.22	3,055	981
7	58+45 to 71+78	Gneiss....	.....do......	1,333	2,369.78	256.70	31.64	3,759	1,208
8	71+78 to 78+65	...do......	Asphalt A..	687	1,221.33	132.32	16.30	1,929	635
9 12	78+65 to 89+50 126+95 to 153+00	Gravel....	Asphalt Y.	1,085 2,605	6,863.22	969.60	47.09	13,442	3,431
10	89+50 to 118+10	...do......	Asphalt B..	2,860	5,445.22	618.20	37.23	8,388	2,614
11	118+10 to 126+95	...do......	Tar........	885	1,573.34	204.10	10.68	2,818	786
15	173+00 to 182+80	Trap......	Asphalt A..	980	1,742.22	205.14	40.72	2,740	871
16	182+80 to 192+00	...do......	Asphalt X.	920	1,621.34	192.18	38.07	2,500	746
19	215+28 to 225+10	Granite...	.....do.....	982	1,728.00	146.84	23.89	3,016	968
20	225+10 to 235+50	...do......	Asphalt A..	1,040	1,866.67	158.66	25.81	3,249	952
	Total........	....	....	....	....	3,414.20	347.21	48,000	14,088

Experiment No.	Station.	Total costs.								
		Stone on siding.	Unloading stone.	Hauling stone.	Chips on siding.	Unloading chips.	Hauling chips.	Binder bitumen on siding.	Hauling binder bitumen.	Seal bitumen on siding.
3	18+00 to 28+10	$613.67	....	$171.50	$86.01	....	$24.31	$381.79	$7.17	$110.21
4	28+10 to 38+10	602.09	....	168.93	87.52	....	24.51	198.58	7.06	63.76
7	58+45 to 71+78	320.87	....	69.15	38.92	....	8.68	244.29	8.69	78.52
8	71+78 to 78+65	165.41	....	35.74	20.05	....	4.36	237.27	4.46	78.10
9 12	78+65 to 89+50 126+95 to 153+00	64.64	$72.92	153.42	52.27	....	50.59	793.08	31.06	202.43
10	89+50 to 118+10	41.21	46.50	97.81	41.33	....	39.82	1,065.15	19.38	331.98
11	118+10 to 126+95	13.61	15.35	32.31	11.85	....	11.84	281.80	6.51	78.60
15	173+00 to 182+80	297.45	34.19	21.36	75.33	$6.79	4.18	347.98	6.33	110.62
16	182+80 to 192+00	278.66	32.03	20.02	70.43	6.35	3.92	162.50	5.78	48.49
19	215+28 to 225+10	209.98	24.34	....	34.16	3.97	5.40	196.04	6.97	62.92
20	225+10 to 235+50	226.89	26.33	....	36.91	4.31	5.85	412.62	7.51	120.90
	Total........	2,834.48	251.66	770.24	554.78	21.42	183.46	4,321.10	110.92	1,286.53

Experiment No.	Station.	Total costs.								
		Hauling seal bitumen.	Heating and mixing.	Hauling mix.	Spreading mix.	Rolling mix.	Applying seal bitumen.	Spreading chips.	Rolling seal.	Total cost.
3	18+00 to 28+10	$2.07	$119.21	$98.21	$22.22	$4.47	$10.15	$9.63	$1.49	$1,662.11
4	28+10 to 38+10	2.27	121.77	99.79	22.58	6.18	11.55	10.32	2.06	1,428.97
7	58+45 to 71+78	2.79	160.39	71.65	24.15	7.99	21.51	18.98	3.53	1,080.11
8	71+78 to 78+65	1.47	82.63	36.91	12.44	3.99	11.46	9.78	1.76	705.83
9 12	78+65 to 89+50 126+95 to 153+00	7.93	481.88	185.98	80.53	27.10	57.78	31.44	9.24	2,302.29
10	89+50 to 118+10	6.04	382.11	147.42	63.83	21.33	45.45	24.85	7.29	2,381.50
11	118+10 to 126+95	1.82	110.60	42.72	18.49	6.27	13.60	7.13	2.15	654.65
15	173+00 to 182+80	2.01	114.51	78.47	19.47	6.60	8.72	9.91	1.85	1,145.77
16	182+80 to 192+00	1.72	106.90	73.41	18.21	6.18	8.05	9.32	1.70	853.67
19	215+28 to 225+10	2.24	173.63	95.17	51.46	18.74	28.85	14.33	9.37	937.57
20	225+10 to 235+50	2.20	186.85	102.27	55.31	20.31	30.65	15.49	10.15	1,264.55
	Total.......	32.56	2,040.48	1,032.00	388.69	129.16	247.77	161.18	50.59	14,417.02

PRICES OF LABOR AND MATERIALS.

The above cost data are based upon the following unit costs for labor and for materials (f. o. b. nearest siding):

Common labor, per day, $1 to $2.
Skilled labor, per day, $2.50 to $3.
Teams, per day, $4 to $4.50.
Foremen, per day, $2 to $2.50.
Carpenters, per day, $2.25 to $4.50.
Rollermen, per month, $65 to $75.
Mixing-plant engineer, per month, $80.
Motor-truck drivers, per month, $100.
Steam shovel engineer, per month, $150.
Foremen, per month, $75 to $150.
Timekeeper, per month, $80.
Superintendent, per month, $150.
Sandstone, all sizes, per ton, $1.37.
Gneiss, 1½-inch, per ton, $1.21.
Gneiss, ¾-inch, per ton, $1.25.
Gneiss chips, per ton, $1.85.
Trap, 1½-inch, per ton, $1.25.
Trap, ¾-inch, per ton, $1.45.
Trap chips, per ton, $1.85.
Granite, all sizes, per ton, $1.43.
Gravel, pit-run, per ton, $0.06⅔.
Gravel, pea, per ton, $1.11.
Asphalt A, per gallon, $0.123 and $0.127.
Asphalt B, per gallon, $0.127.
Asphalt X, per gallon, $0.65.
Asphalt Y, per gallon, $0.059.
Refined tar, per gallon, $0.100.
Cement, per barrel, $1.65.
Washed gravel, per ton, $0.95.
Sand, per ton, $0.83.
Lumber, per thousand, $17 to $26.
Reinforcing steel, per pound, $0.02.
Coal, per ton, $3.75 to $4.25.
Wood, fuel, slabs, per load, $1.
Cast-iron pipe, 10-inch, per foot, $0.75.
Cast-iron pipe, 12-inch, per foot, $0.85 and $0.88.
Cast-iron pipe, 16-inch, per foot, $1.16.
Cast-iron pipe, 18-inch, per foot $1.58.
Corrugated-metal pipe, 15-inch, per foot, $0.66⅔, $0.67, $0.99 9/10, and $1.00.
Corrugated metal pipe, 18-inch, per foot, $0.65, $0.78¼, and $1.15.
Corrugated metal pipe, 24-inch, per foot, $0.93¼ and $1.26.

Additional items of depreciation, repairs, interest, and rental on equipment:

Steam shovel	$735.00
Industrial railway equipment	200.00
Pile driver	50.00
Mixing plant	651.21
Penetration equipment	208.00
Rollers	750.00
Wagons	105.00
Plows, scarifier, hand tools, scales	421.50

Table 23 gives the results of a traffic census taken before and after improvement of the road.

TABLE 23.—*Volume and character of traffic on Mount Vernon Avenue at Mount Ida.*

		Average before improvement.[1]		Average after improvement.[2]	
		North.	South.	North.	South.
1	Loaded 1-horse wagon	8	10	12	12
2	Unloaded 1-horse wagon	3	2	0	0
3	Loaded 2-horse wagon	5	10	4	3
4	Unloaded 2-horse wagon	8	5	1	2
5	Loaded 4-horse wagon	0	0	0	0
6	Unloaded 4-horse wagon	0	0	0	0
7	1-horse pleasure vehicle	6	7	3	3
8	2-horse pleasure vehicle	0	0	0	0
9	Rubber-tired horse vehicle	0	0	0	0
10	Saddle horse	4	2	0	0
11	Motor cycle	3	3	2	2
12	Excessively heavy vehicle	0	0	0	0
13	Motor runabout	0	0	9	9
14	Motor touring car	20	20	83	81
15	Loaded motor dray	3	3	9	6
16	Unloaded motor dray	1	1	0	0

[1] Average of 8 days in March and 7 days in June, 1915.
[2] Average of 7 days in December, 1915.

EXPERIMENTS ON FALLS ROAD, MONTGOMERY COUNTY, MD.

SURFACE TREATMENT (OILS, TAR PREPARATIONS, REFINED TARS).

In the summer of 1913 a series of bituminous surface treatments was applied to Rockville Pike in Montgomery County, Md. The original report of these experiments is given in U. S. Department of Agriculture Bulletin No. 105 and a subsequent report of behavior was made in Department Bulletin 257. In order to make it possible to check the data secured from several of these experiments, another series of comparative test sections was constructed on the Falls Road, leading from Rockville to Potomac, Md. In the Falls Road series, sections 1, 2, 4, and 5 were treated with bituminous materials similar to those used on Rockville Pike sections 3, 5, 2, and 1, respectively. The coal-tar preparation selected for Experiment No. 3 on Falls Road had not been used in any previous service tests in this vicinity. Conditions surrounding the two experimental roads are much the same, except that traffic is lighter and the proportion of horse-drawn vehicles greater on the Falls Road.

The specifications prescribed a uniform application of one-half gallon of bituminous material per square yard, but the amount was varied according to the surface condition of the several sections. The road surface was dry when the applications were made, and fine gravel was used to cover the bituminous material. The mechanical analysis of the gravel used is given in Table 24.

The bitumen was transported to the road and spread by means of two 1,200-gallon automobile distributors equipped with speed and pressure gauges. The length of the nozzle-line was so adjusted that one-half of the width of the road was sprayed at one time. The nozzles were of the right-line type, from which the bitumen was applied in a fan-shaped spray under a uniform pressure of approximately 25 pounds.

The Falls Road was reconstructed in 1913, and surfaced with water-bound macadam 15 feet wide. Early in the summer of 1915, when the experimental test sections were planned, the macadam surface had become thoroughly compacted, and, with a few exceptions, was smooth, free from ruts or depressions, and in good condition to receive the bituminous material. In August the contractor distributed all the gravel required for the work with a two-ton motor truck before he began the application of the bituminous materials. The action of this truck was so severe that when the gravel had been distributed, the water bond in sections 1, 2, and part of 3 was completely broken, and several weak places in the foundation in section 2 had formed. The latter were repaired, and an effort was made to reestablish the water bond. Owing to the protracted drought and the disturbing action of traffic, this work was only partially successful. The condition of the surface of each section at the time of treatment is discussed in detail in connection with each experiment. The cost of this repair work was $70.

Experiment No. 1 begins at the city limits of Rockville, and the remainder of the series follow in regular numerical order. The details of the work are subjoined.

TABLE 24.—*Mechanical analysis of gravel used on Rockville-Potomac Road.*

	Per cent.
Passing $\frac{3}{4}$-inch screen, retained on $\frac{1}{2}$-inch screen	9. 8
Passing $\frac{1}{2}$-inch screen, retained on $\frac{1}{4}$-inch screen	62. 2
Passing $\frac{1}{4}$-inch screen, retained on $\frac{1}{8}$-inch screen	25. 2
Passing $\frac{1}{8}$-inch screen	2. 8
Total	100. 0

EXPERIMENT NO. 1.—ASPHALTIC PETROLEUM, COLD APPLICATION, CORRESPONDING TO EXPERIMENT NO. 3, ON ROCKVILLE PIKE.

Location: Station 0+00 to station 4545+75.
Length: 4,575 feet.
Total area: 7,625 square yards.
Date of application: September 23 and 24.
Temperature of petroleum: About 90° to 100° F.

TABLE 25.—*Analysis of asphaltic petroleum used in Experiment No. 1.*

Specific gravity, 25°/25° C.	0. 944
Flash point, ° C.	26
Burning point, ° C.	90
Viscosity, Engler 50 c. c. at 25° C., specific	86. 6
Loss, 5 hours at 163° C., 20 grams, per cent	26. 54
Float test on residue at 50° C. (time)	2′ 0″
Per cent of total bitumen insoluble in 86° B. naphtha	13. 70
Fixed carbon, per cent	7. 93
Soluble in CS_2 (total bitumen), per cent	99. 94
Organic matter insoluble, per cent	. 06
Inorganic matter insoluble, per cent	. 00
Total	100. 00

Except for a few short sections, the total length of which did not exceed 300 feet, the stone in the surface of Experiment No. 1 was loose and covered with a layer of dust. The surface was swept lightly to avoid displacing the stone, and masses of undesirable matter were removed with hoes and shovels. In order to facilitate the adhesion of the petroleum to the dusty stones, much hand-brooming was required. The oil was permitted to lie for about 2 hours before the gravel was applied. The oil was shipped in a tank car, which was placed about 1 mile from the beginning of the section.

EXPERIMENT NO. 2.—RESIDUAL ASPHALTIC PETROLEUM, HOT APPLICATION, CORRESPONDING TO EXPERIMENT NO. 5, ON ROCKVILLE PIKE.

Location: Station 45+75 to station 89+61.
Length: 4,386 feet.
Total area: 7,310 square yards.
Date of application: September 27 and 28.
Temperature of bitumen: 180° F.

TABLE 26.—*Analysis of residual asphaltic petroleum used on experiment No. 2.*

Specific gravity, 25°/25° C	0.981
Viscosity engler, 100° C, 50 c. c., specific	16.8
Loss, 5 hours, at 163° C., 20 grams, per cent	5.81
Float test on residue at 50° C	2′ 8″
Per cent of total bitumen insoluble in 86° B. naphtha	17.83
Fixed carbon, per cent	10.23
Soluble in CS_2 (total bitumen) per cent	99.93
Organic matter, insoluble, per cent	.07
Inorganic matter, insoluble, per cent	.00
Total	100.00

The condition of the road surface was similar to that in section No. 1, except that the combined total length of areas in which the water bond was unbroken approximated 700 feet. In several places the foundation had failed, and extensive repairs and the digging of drainage ditches were necessary. The petroleum was delivered in a tank car in which it was heated by steam from a traction engine. Owing to the loose condition of the surface, practically three-quarters of a gallon of petroleum were applied per square yard. Much hand brooming of the petroleum was required to cause it to adhere to the dusty stone and produce uniform distribution. About three hours elapsed between spreading the oil and covering it with gravel. About 15 cubic yards of gravel were subsequently required on the firm portions of the road to take up the exuding bitumen.

EXPERIMENT NO. 3.—COAL-TAR PREPARATION, COLD APPLICATION.

Location: Station 89+61 to station 169+02.
Length: 7,941 feet.
Total area: 13,235 square yards.
Date of application: October 11, 12, and 13.
Temperature of preparation: about 90° to 100° F.

TABLE 27.—*Analysis of coal-tar preparation*[1] *used on experiment No. 3.*

	Per cent by volume.	Per cent by weight.
Specific gravity, 25°/25° C		1.144
Viscosity, Engler, 50 c. c. at 40° C., specific		10.4
Free carbon (insoluble in CS_2) per cent		5.53
Distillation:		
Water	[2] 1.8	1.6
First light oils (to 110° C)	[3] .7	.4
Second light oils (110° to 170° C.)	[3] 1.0	.6
Heavy oils (170° to 270° C.)	[3] 23.2	20.1
Heavy oils (270° to 315° C.)	[3] 10.2	8.9
Pitch residue	[4] 63.1	68.3
Total	100.0	99.9

All but 500 linear feet of the road surface near the south end of the section was in excellent condition to receive the surface treatment. The section was thoroughly swept with horse-drawn rotary sweepers, and the tar adhered uniformly to the surface rock without the aid of hand brooming. After about 500 linear feet of surface had been sprayed, the distributor was stopped and the gravel was spread immediately to prevent the tar from flowing off the surface over the shoulders. The tar preparation was shipped in a tank car, which was placed 2½ miles from the near end of section 3.

EXPERIMENT NO. 4.—REFINED WATER-GAS TAR, COLD APPLICATION, SIMILAR TO EXPERIMENT NO. 2 ON ROCKVILLE PIKE.

Location: Station 169+02 to station 226+20.
Length: 5,718 feet.
Total area: 9,530 square yards.
Date of application: September 22 and 23.
Temperature of tar: About 130° F.

TABLE 28.—*Analysis or refined water-gas tar used on experiment No. 4.*

	Per cent by volume.	Per cent by weight.
Specific gravity, 25°/25° C		1.132
Viscosity, Engler, 50 c. c. at 50° C., specific		16.2
Free carbon (insoluble in CS_2), per cent		0.64
Distillation:		
Water	0.0	0.0
First light oils (to 110° C)	.0	.0
Second light oils (110° to 170° C.)	[2] 1.5	1.0
Heavy oils (170° to 270° C.)	[3] 21.5	18.9
Heavy oils (270° to 315° C.)	[2] 15.0	13.4
Pitch residue	[4] 62.0	66.6
Total	100.0	99.9

The surface of this section was in excellent condition and no repairs were required. The experiment was conducted in all respects like experiment No. 3. The tar when delivered in the distributors from the plant was still slightly warm from the refining process. The distance from the plant to the near end of the section was about 12 miles.

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[1] Thin fluid.
[2] Clear.
[3] Cloudy.
[4] Hard, glossy, semisolid.

EXPERIMENT NO. 5.—REFINED COAL TAR, HOT APPLICATION, SIMILAR TO EXPERIMENT NO. 1, ON ROCKVILLE PIKE.

Location: Station 226+20 to station 295+00.
Length: 5,880 feet.
Total area: 9,800 square yards.
Date of application: September 13, 14, 15, and 16.
Temperature of tar: 180° F.

TABLE 29.—*Analysis of refined coal tar used on experiment No. 5.*

Specific gravity, 25°/25° C.		1.181
Float test at 32° C. (time)		1′ 45″
Free carbon (insoluble in CS_2), per cent		9.39
Distillation:	Per cent by volume.	Per cent by weight.
Water	0.0	0.0
First light oils (to 110° C)	.0	.0
Second light oils (110° to 170° C.)	.0	.0
Heavy oils (170° to 270° C.)	13.5	11.4
Heavy oils (270° to 315° C.)	13.2	11.3
Pitch residue	73.3	77.8
Total	100.0	100.5

The surface of section No. 5 was also in excellent condition, and the experiment was conducted similarly to experiments Nos. 3 and 4. The bitumen was prepared in a local plant and was hauled to the work in the distributors ready for application. The haul from the plant to the near end of the section was about 11 miles.

The cost data given in Table 30 are based upon the following unit prices for labor and materials.

Foreman, per 8-hour day	$4.00
Distributor operator, per 8-hour day	2.50
Roller operator, per 8-hour day	3.00
Motor-truck driver, per 8-hour day	2.50
Teams, per 8-hour day	4.00
Laborers, per 8-hour day	1.60–2.00
Gravel on siding, per ton	1.65
Asphaltic petroleum on siding, per gallon	[1] .05
Residual asphaltic petroleum on siding, per gallon	[1] .07½
Coal-tar preparation on siding, per gallon	[1] .09½
Refined water-gas tar at plant, per gallon	[1] .08½
Refined coal tar at plant, per gallon	[1] .08

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[1] Estimated.

TABLE 30.—*Materials and cost data for surface-treatment experiments on Falls Road.*

Experiment No.	Corresponding to Rockville Pike Experiment No.	Description.			Quantity of materials (per square yard).		Cost per square yard.	
		Bituminous material.	Length of section.	Area of section.	Bituminous material.	Gravel.[1]	Bituminous material.	Gravel (hauling included).
			Feet.	*Sq. yds.*	*Gallon.*	*Cu. yds.*	*Cents.*	*Cents.*
1	3	Asphalt petroleum (cold)	4,575	7,625	0.525	0.0149	2.63	3.84
2	5	Residual asphaltic petroleum (hot)	4,386	7,310	.739	.0164	5.54	4.25
3	......	Coal-tar preparation (cold)	7,941	13,235	.423	.0151	4.02	3.53
4	2	Refined water-gas tar (cold)	5,718	9,530	.538	.0150	4.57	3.67
5	1	Refined coal tar (hot)	5,880	9,800	.596	.0150	4.77	3.65

Experiment No.	Description.	Cost per square yard.						Total cost.	
	Bituminous material.	Cleaning surface.	Heating bituminous material.	Hauling and applying hot material.[2]	Spreading gravel.	Rolling.	Miscellaneous.[3]	Per square yard.	Per mile, 15-foot road.
		Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	
1	Asphaltic petroleum (cold)	0.05	....	0.23	0.32	0.05	0.65	7.77	$683.76
2	Residual asphaltic petroleum (hot)	.05	0.41	.37	.71	.10	.68	12.11	1,065.68
3	Coal-tar preparation (cold)	.01	....	.12	.38	.04	.38	8.48	746.24
4	Refined water-gas tar (cold)	.04	....	.24	.55	.04	.52	9.63	847.44
5	Refined coal tar (hot)	.08	....	.32	.86	.02	.51	10.21	898.48

[1] 2,500 pounds equals 1 cubic yard.
[2] Hauled to road in distributor.
[3] General expense and superintendent.

INSPECTION REPORT.

The following report describes the condition of the experiments on the Falls Road on the date of last inspection, April 27, 1916.

Experiment No. 1.—At the time of the inspection the surface did not appear to carry a distinct mat or carpet and the bituminous treatment was worn very thin and showed a tendency to crumble, even on warm days. It is probable that a re-treatment will be necessary early in the spring as the aggregate of the macadam shows quite generally throughout the central portion of the road.

Experiment No. 2.—This section has a black, leathery mat which is easily marked by the calks of passing horses, but irons out under the wheels so that there is no indication of "picking up" or disintegration. In a few places additional gravel had to be spread to prevent bleeding, and it is probable that more top-dressing will be required as soon as hot weather prevails. At the present time very little stone shows in the mat.

Experiment No. 3.—The gravel used for top-dressing plainly shows everywhere on this section and an excess still remains along the sides. The mat is a hard, stone-filled carpet, practically unbroken, and shows no signs of failure anywhere. In general this was the best appearing section of the road at the time of the inspection.

Experiment No. 4.—The appearance of this section is similar to that of experiment No. 3, but the mat is thinner and the limestone aggregate of the macadam is slightly but quite uniformly visible over the entire section along the central portion of the road. Some excess top-dressing still remains along the shoulders. It is probable that the section will require re-treatment in the spring.

Experiment No. 5.—The mat on this section is softer than that on sections 3 and 4, but much less leathery than that on section 2. The macadam shows through in a few places, but the mat is not broken at any point. It is probable that this section will require a re-treatment late in the summer or fall. About 300 feet from the south end of the section there is an area about 20 feet in length and extending nearly the entire width of the road, where the surface was rather badly burned as the result of the burning of a blacksmith shop and stables near the road.

EXPERIMENTS ON BRADLEY LANE, MONTGOMERY COUNTY, MD.

BITUMINOUS MACADAM (PENETRATION METHOD).

The experiments previously reported for this road have been discontinued because the design was considered inadequate for the prevailing traffic. The traveled way was only 10 to 12 feet wide, while the road carried practically as heavy traffic as the adjacent section of the Rockville Pike. Partly also because of the exceedingly poor drainage and foundation conditions, it had never been possible to maintain the surface satisfactorily, and it had become rutted and was continually breaking into potholes, while the edges were badly cut and sheared by traffic. Finally, in June, 1915, arrangements were made to reconstruct the roadway as a new experiment, and a bituminous macadam surface, constructed according to the penetration method, was the type of improvement adopted.

The old surface-treated macadam was scarified, reshaped, and widened by the addition of new material to form the foundation course for the new surface. The total length of the road is 3,813.5 feet. The width of the new roadway was made 16½ feet from Connecticut Avenue westward for approximately 2,404 feet by adding 2½ feet to the south side and 4 feet to the north side of the old surface; the remaining distance to Wisconsin Avenue was made 15 feet wide by adding 2½ feet to each side of the old surface. In preparing the foundation course it was necessary to add 145 tons of new limestone; and in order to increase the stability of the foundation, 3,646 linear feet of 4-inch drain tile was used. The drain tile was placed under the south gutter of the road at a depth of a foot or more below the surface, and is expected to correct the unsatisfactory foundation condition referred to in the preceding paragraph. The drainage was further improved by cleaning out all existing culverts and paving culvert inlets and outlets with gneiss spalls where this was necessary. Two existing catch basins which were considered too small for the service demanded of them were reconstructed and enlarged and two new catch basins were constructed at other points.

After the foundation course was thoroughly compacted by rolling, an entirely new wearing surface was constructed. The wearing surface consists of a 3-inch depth of fresh limestone (loose measurement) bonded together with bituminous material. The same bituminous material was used throughout, but two different methods were employed. From station 0+00 to station 19+00 and from station 21+00 to station 38+13½ straight oil-asphalt was used, while for the remaining 200 feet between stations 19 and 21 a sand-oil-asphalt grout was used.

THE OIL-ASPHALT SECTION (PENETRATION METHOD).

Location: Station 0+00 to station 19+00 and station 21+00 to station 38+13½.
Area: 6,421 square yards.

These sections comprise a total area of 6,421 square yards and were constructed in accordance with the common penetration method; that is, the penetration course of stone was spread and rolled, bitumen applied, screenings spread, and the surface finished with a seal coat of bitumen and stone chips.

One and a half gallons of bitumen per square yard was used in the penetration course and approximately one-half gallon per square yard in the seal coat. A total of 7,150 gallons of bitumen was used on the first section and 6,328 gallons on the second section, which gives a total average quantity per square yard of 2.012 gallons and 2.16 gallons, respectively, for the two sections. Table 31 shows the analysis of the oil-asphalt used, and Table 32 the cost of the work, which was done by contract.

TABLE 31.—*Analysis of oil-asphalt.*[1]

Specific gravity 25°/25° C.	1.024
Melting point °C.	50
Penetration 25° C., 100 grams, 5 seconds	105
Loss 5 hours at 163° C., 20 grams, per cent	.19
Penetration of residue[1] as above	64
Percentage of total bitumen insoluble in 80° naphtha	25.77
Fixed carbon, per cent	15.74
Soluble in CS_2 (total bitumen), per cent	99.70
Organic matter insoluble, per cent	.18
Inorganic matter insoluble, per cent	.12
Total, per cent	100.00

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[1] Fairly hard, glossy, sticky, semisolid.

TABLE 32.—*Unit and total costs.*

Items.	Unit cost.	Total cost.
Clearing and grubbing, lump sum	....	$79.61
Excavation, 793 cubic yards	$0.4704	373.03
Subdrains, 3,646 feet 4-inch tile	.2145	782.07
Scarifying, 5,316 square yards	.0304	161.61
Shaping shoulders and subgrade, 4,064 square yards	.0371	150.87
Foundation stone, 146,775 tons in place	2.196	322.32
Wearing course, penetration method, 6,421 square yards	.3284	2,108.66
Wearing course, sand-oil grout, 367 square yards	.3942	144.66
Total	....	4,122.83

SAND-OIL GROUT (PENETRATION METHOD).

Location: Station 19+00 to station 21+00.
Area: 366.7 square yards.

This section includes two experiments in the use of oil asphalt mixed with sand for constructing a bituminous macadam surface according to the penetration method. The first experiment extends from station 19+00 to station 19+55, and was constructed in a manner exactly similar to that described above for the straight penetration work, except that 50 per cent by volume of sand was used with the bituminous material. The second experiment extends from station 19+55 to station 21+00 and was constructed in a similar manner to the preceding, except that only 33 per cent by volume of sand was used with the bituminous material.

A total of 672 gallons of oil asphalt were used in the two experiments, which is at the rate of about 1.83 gallons per square yard. It appears, therefore, that the saving in bituminous material which was effected by employing this method is only about 0.2 gallon per square yard; and if the cost of heating the sand and mixing the oil-sand grout is considered, the cost was greater with this method than with the ordinary penetration method by about 2 cents per square yard. It is very questionable, therefore, if the experiment will prove of value. It will be kept under close observation, however, with a view to ascertaining any possible superiority which this section may possess over the ordinary penetration sections.

EXPERIMENTS AT WASHINGTON. D. C.

BITUMINOUS CONCRETE.

The bituminous concrete experiments at Washington, D. C., consisted in the construction of two wing drives leading from the sheet-asphalt pavement in front of the main building of the United States Department of Agriculture to the sheet-asphalt plaza in the rear, and was completed on December 7, 1915. Each of the drives is approximately 140 feet long and 18 feet wide. The type of construction was bituminous concrete upon a 6-inch foundation of Portland cement concrete. Sand and gravel of the mechanical analyses given in Tables 33 and 34 were used in the concrete, which was mixed in a mechanical mixer and allowed to stand 10 days before the wearing surface was applied. The proportion of the mix, by volume, was 1 part cement, 3 parts sand, 7 parts gravel.

Two types of bituminous concrete were chosen for the wearing course, which was spread so as to compact to a thickness of 2 inches. The northern half of each drive was surfaced with a mixture prepared according to the Topeka specification, while the southern half of each was paved with bituminous concrete prepared according to the District of Columbia specification. The analyses of the bituminous aggregates of these preparations are given in Table 35 and Table 36, respectively. An analysis of the oil-asphalt is given in Table 37.

The bituminous concrete was prepared in a local plant and was delivered to the site of the work in trucks at a temperature of 220° F. or more. After being spread and sufficiently cooled the mixture was given a preliminary rolling with a 3-ton tandem roller and was finished with a 12-ton roller. A seal coat of oil-asphalt represented by the analysis given in Table 37 was spread with a squeegee on the areas surfaced with the District of Columbia mixture, and covered with hot stone chips immediately. In the case of the Topeka mixture the seal coat was omitted and the surface was dusted lightly with Portland cement.

TABLE 33.—*Mechanical analysis of sand used in concrete base.*

	Per cent.
Total retained on 10-mesh sieve	10. 2
Total retained on 20-mesh sieve	33. 9
Total retained on 30-mesh sieve	53. 9
Total retained on 40-mesh sieve	66. 4
Total retained on 50-mesh sieve	77. 9
Total retained on 80-mesh sieve	95. 9
Total retained on 100-mesh sieve	96. 5
Total retained on 200-mesh sieve	97. 9
Passing 200-mesh sieve	2. 0

TABLE 34.—*Mechanical analysis of gravel used in concrete base.*

	Per cent.
Total retained on 1¼-inch screen	2. 1
Total retained on 1-inch screen	5. 5
Total retained on ¾-inch screen	18. 1
Total retained on ½-inch screen	34. 7
Total retained on ¼-inch screen	70. 7
Total retained on 10-mesh sieve	94. 0
Passing 10-mesh sieve	6. 0

TABLE 35.—*Analysis of bituminous concrete (Topeka specification).*

	Per cent.
Bitumen soluble in CS_2	8.25
Mineral aggregate:	
Passing ½-inch screen, retained on ¼-inch screen	7.9
Passing ¼-inch screen, retained on 10-mesh sieve	17.2
Passing 10-mesh sieve, retained on 20-mesh sieve	17.3
Passing 20-mesh sieve, retained on 30-mesh sieve	9.8
Passing 30-mesh sieve, retained on 40-mesh sieve	9.3
Passing 40-mesh sieve, retained on 50-mesh sieve	10.2
Passing 50-mesh sieve, retained on 80-mesh sieve	14.2
Passing 80-mesh sieve, retained on 100-mesh sieve	2.7
Passing 100-mesh sieve, retained on 200-mesh sieve	7.5
Passing 200-mesh sieve	3.9
Total	100.0

TABLE 36.—*Analysis of bituminous concrete (District of Columbia specification).*

	Per cent.
Bitumen soluble in CS_2	7.2
Mineral aggregate:	
Passing 1-inch screen, retained on ¾-inch screen	6.8
Passing ¾-inch screen, retained on ½-inch screen	14.4
Passing ½-inch screen, retained on ¼-inch screen	24.3
Passing ¼-inch screen, retained on 10-mesh sieve	14.0
Passing 10-mesh sieve, retained on 20-mesh sieve	7.5
Passing 20-mesh sieve, retained on 30-mesh sieve	6.1
Passing 30-mesh sieve, retained on 40-mesh sieve	6.4
Passing 40-mesh sieve, retained on 50-mesh sieve	6.2
Passing 50-mesh sieve, retained on 80-mesh sieve	4.4
Passing 80-mesh sieve, retained on 100-mesh sieve	1.1
Passing 100-mesh sieve, retained on 200-mesh sieve	4.4
Passing 200-mesh sieve	4.4
Total	100.0

TABLE 37.—*Analyses of oil asphalts used in experiments at Washington, D. C.*

Use.	Bituminous concrete.	Seal coat.
Specific gravity 25°/25° C.	1.055	1.055
Melting point, ° C.	55	58.5
Penetration at 25° C., 100 grams, 5 seconds	63	47
Loss, 5 hours at 163° C., 20 grams, per cent	.56	.31
Penetration of residue, as above	40	34
Per cent of total bitumen insoluble in 86° C. naphtha	26.40	31.76
Fixed carbon, per cent	19.32	19.33
Soluble in CS_2 (total bitumen), per cent	98.39	99.88
Organic matter insoluble, per cent	.70	.11
Inorganic matter insoluble, per cent	.91	.01
Total, per cent	100.00	100.00

The cost data given in Table 38 is based on unit costs of labor and material as follows, and represents approximately the contractor's cost:

Labor:	
1 foreman, per day	$4.00
1 foreman, per day	2.50
Laborers, per hour	0.20–0.40
Teams, per hour	.60
Materials on road:	
Cement, per barrel	1.32
Sand for concrete, per ton	.55
Gravel for concrete, per ton	.65
Bituminous concrete on road (estimated), per square yard	.40
Oil asphalt for seal coat, per gallon	.10
Stone chips for seal coat, per ton	1.00

TABLE 38.—*Materials and cost data for bituminous-concrete experiments at Washington, D. C.*

General.	Detail.	District of Columbia specification.	Topeka specification.
Materials for base, per square yard of pavement	Cement, barrel	0.115	0.115
	Sand, ton	.075	.075
	Gravel, ton	.165	.165
Materials for surface, per square yard of pavement	Bituminous concrete	(1)	(1)
	Bituminous seal coat, gallons.	.30	
	Cement used on surface, barrels.		.003
	Stone chips for seal coat, tons	.015	
Costs for base per square yard of pavement, in cents	Prepared subgrade	20.88	20.88
	Cement	15.16	15.16
	Sand	4.09	4.09
	Gravel	10.70	10.70
	Header strips in place	4.43	4.43
	Mixing and laying concrete	10.08	10.08
Costs for surface per square yard of pavement, in cents.	Bituminous concrete on road	40.00	40.00
	Spreading	8.90	8.90
	Rolling	.90	.90
	Bituminous seal coat	3.00	
	Chips for seal coat	1.50	
	Applying seal coat	1.40	
	Cement on surface		.40
Total		121.04	115.54

[1] Not determined.

EXPERIMENTS AT BUENA VISTA, FLA.

RESIDUAL ASPHALTIC PETROLEUM-CORALLINE ROCK.

As a result of observation of the behavior of the various experimental sections built on Biscayne Drive at Miami in 1913, and reported in Department Bulletin No. 105, it was decided to construct another section similar in all respects to section No. 6, except that a heavier asphaltic material, better suited for use with coralline rock, was to be employed.

The work was done on the driveway leading from the Miami-Lemon City Road into the grounds of the experimental gardens of the United

States Department of Agriculture, located about 3 miles north of Miami. The roadway is 1,725 feet long and is 12 feet and 16 feet in width. The traffic to which it is subjected is light, and originates on the grounds of the experimental gardens.

The site is a new location, which was cleared, grubbed, and graded immediately before the surfacing was undertaken. After leaving the Miami-Lemon City Road, the first 600 feet was a deep sand bed, while the remainder was a succession of ridges of coralline rock, with sand beds intervening. The coralline ridges were excavated, and a uniform sand subgrade was prepared.

The surfacing materials used were coralline rock and a heavy asphaltic oil. The properties of the rock as it occurs near Miami are noted in U. S. Department of Agriculture Bulletin No. 105. The subgrade, which was 6 inches thick, loose, was built of coralline fieldstone gathered on or near the site of the project, sledged on the subgrade and thoroughly rolled.

The rock for the wearing course was taken from a county pit about 1 mile from the road. The fine material resulting from blasting was eliminated by screening the rock over one-fourth inch stationary screens. The wearing course was 3 inches thick, loose, and was rolled once over with an 8-ton macadam roller before the bituminous material was applied. The cross section of the road shows a crown slightly less than one-half inch per foot.

The properties of the bituminous material are stated in Table 39. This material was delivered in barrels, heated in 1-barrel kettles, and applied by means of hand-pouring pots. From 1 to 3 hours after it had been poured the bituminous material was covered with about one-half inch of sand which had been taken from the roadside and screened to remove twigs, roots, etc. The sanded surface was then rolled until all visible movement of the surface particles ceased, after which the road was opened to traffic.

The cost of the various processes involved in the construction of this section are given in Table 40. The cost data are based on labor and material as follows:

Superintendent, per day	$4.00
Foreman, per day	3.00
Teams, per day	5.00
Labor, per day	1.50
Roller, per day	6.00
Bitumen, per gallon	.134

TABLE 39.—*Analysis of residual asphaltic petroleum used at Buena Vista, Fla.*

Specific gravity 25°/25° C	0.992
Viscosity, Engler, 50 c. c. at 100° C. specific	31.5
Float test at 32° C., time	2′ 44″
Float test at 50° C., time	1′ 04″
Loss at 163° C. 5 hours, 20 grams, per cent	.75
Float test of residue at 50° C., time	1′ 30″
Per cent of total bitumen insoluble in 86° B. naphtha	13.02
Fixed carbon, per cent	8.20
Soluble in CS_2 (total bitumen), per cent	99.91
Organic matter insoluble, per cent	.09
Inorganic matter insoluble, per cent	.00
Total, per cent	100.00

TABLE 40.—*Cost data on construction of coralline-rock road.*

Materials used:	
No. 2 stone, cubic yard per square yard	0.083
Sand, cubic yard per square yard	.014
Bitumen, gallon per square yard	.906
Coat per square yard:	
No. 2 stone	$0.1546
Bitumen	.1243
Spreading No. 2 stone	.0175
Heating and applying bitumen	.0075
Spreading sand	.0105
Rolling	.0079
General expense	.0186
Total	.3409
Total costs for surface:	
Quarrying and crushing No. 2 stone, 227 cubic yards	302.85
Loading and hauling No. 2 stone to road	118.00
Spreading No. 2 stone	47.50
Bitumen on siding, 2,465 gallons	330.31
Unloading and hauling bitumen to road	8.00
Heating and applying bitumen	20.40
Spreading sand, 38 cubic yards	28.75
Rolling	21.60
General expense	50.60
Total	928.01
Cost of preliminary work:	
Grading	132.11
Shaping subgrade, 2,722 square yards	51.65
Gathering and hauling foundation stone, 454 cubic yards	125.90
Spreading and sledging foundation stone	95.00
Rolling foundation stone	10.80
Total	415.46

This pavement was completed in May, 1915. When inspected in December, 1915, it showed no evidence of failure or appreciable wear. The normal amount of traffic to which the road will be subjected is not yet developed, and another year will be required to test the wearing qualities of this pavement.

EXPERIMENTS AT JUPITER, PALM BEACH COUNTY, FLA.

OIL-ASPHALT-SAND.

The purpose of this experiment was to demonstrate a simple and inexpensive method of treating the deep sand roads of Florida which are subjected to light traffic. The demonstration section is on West Lateral Road, 1.8 miles north of Jupiter, Fla. The bitumenized portion is 152 feet long and 9 feet wide, skirted on both sides by untreated sand shoulders 5½ feet wide.

The mineral aggregate used was the native sand found in and along the roadway, in which was incorporated asphaltic materials, the properties of which are given in Table 41. The sandbed was prepared for treatment by removing with hand rakes all twigs, sod, and similar undesirable matter from a width 10 feet on each side of the center line of the road. The sand in this area was then smoothed down to a uniform grade, while the cross section was shaped to a total crown of about 5 inches over the 20-foot width.

The bituminous material was heated in 1-barrel kettles and was spread by means of hand-pouring pots in a series of applications, according to what is commonly known as the layer method. Four such applications were made. Each was covered with a layer of sand after the bituminous material had been partly absorbed. The sand for this purpose was obtained from the shoulders. Each layer of sand was thoroughly rolled with a 3-ton horse roller before the succeeding application of bitumen was made. The quantity of bituminous material and the thickness of the sand cushions in the various layers are stated below:

(1) One-third gallon of bitumen A per square yard, over which was spread one-half inch of sand; (2) two-thirds gallon of bituminous material A per square yard which was covered with 1 inch of sand; (3) two-thirds gallon of bituminous material A per square yard, followed by a layer of 1 inch of sand; (4) one-third gallon of a combination of equal parts of A and B per square yard, to which was applied enough sand to absorb the bituminous material.

The resulting cushion of bitumenized sand is approximately 3 inches thick. The original plan involved the use of three layers only, but because of the damp condition of the sand on which the first application of oil was made, the hot asphalt foamed freely and the quantity poured was reduced by one-half. It was necessary, therefore, to add another thin layer to give the desired depth.

After the surface covering of sand was spread, the shoulders and ditches were reshaped and the road was opened to traffic. A few days later the asphalt began to bleed freely, and the local road official in charge covered the road surface with a heavy additional layer of sand to absorb the exudation.

The road was built on April 9 and 10, 1915, and was inspected December 10, 1915. The surface had received practically no attention since the time of its completion. Along the center line or crown of the 9-foot surface the horses had worn a path from 1 to 2 inches deep and about 14 inches wide, and two corresponding wheel ruts extended the full length of the section. The path and ruts are largely in a mass of loose sand, slightly impregnated with bituminous material from 1 to 1½ inches deep which overlies a firm, hard course of bituminized sand. It is evident that the bituminous material used in the fourth layer was of too viscous a nature to assimilate the sand, or was insufficient in quantity to bind the heavy layer of sand which was spread to absorb the bleeding. Outside of the central traveled portion the surface is less broken.

The surface requires reshaping and a light application of material A to bituminize the loose sand thoroughly. The road will then be scarred and rutted by traffic for several months, after which it should be reshaped with a grader occasionally until it is finally compacted.

Table 41.—*Analyses of bituminous materials used in experiment at Jupiter, Fla., 1915.*

	Material.	
	A. Residual asphaltic petroleum.	B. Fluxed native asphalt.
Specific gravity, 25°/25° C	1.01	1.066
Melting point, ° C	....	59
Viscosity, Engler, 50 CC. at 100° C. specific	63.9	....
Float test at 50° C. (time)	2′ 5″	....
Penetration at 25° C. 100 grams, 5 seconds	....	48
Loss at 163° C. 5 hours, 20 grams, per cent	1.82	3.43
Float test of residue at 50° C. (time)	3′ 34″	....
Penetration of residue as above	....	18
Per cent of total bitumen insoluble in 86° B. naphtha	21.22	23.61
Fixed carbon, per cent	12.61	12.02
Soluble in CS_2 (total bitumen), per cent	99.88	95.48
Organic matter insoluble, per cent	.12	1.77
Inorganic matter insoluble, per cent	....	2.75
Total, per cent	100.00	100.00

COST DATA.

This experiment was of too small extent for the cost data to be of material value. The asphalt was donated, and the total labor cost was only about $12.41, including the grading. This is at the rate of about 8.2 cents per square yard, exclusive of the bituminous material.

Since the work was done with convicts and the conditions were favorable, the cost is probably considerably lower than it would have been under ordinary conditions.

EXPERIMENT AT WEST PALM BEACH, FLA.

In May, 1914, a series of seven experimental sections involving the use of coralline rock and bituminous materials was constructed on the Miami-Quebec Highway, about 2 miles south of West Palm Beach. The details of construction are given in U. S. Department of Agriculture Bulletin No. 257. In order to determine the wearing qualities of a sand-asphalt or bituminous-sand surface in comparison with the seven experimental surfaces, a section of this material was added to the series in January, 1915. It is continuous with the other experiments and adjoins section 7.

EXPERIMENT NO. 8.—BITUMINOUS SAND MIXING METHOD.

The original coralline rock road was scarified and reshaped for the foundation. The cross section of the foundation was parallel to the finished surface and 2 inches below it. During the time which elapsed between the preparation of the foundation and the laying of the wearing course, the former was thoroughly compacted by traffic and had become slightly dusty.

In order to secure a sand which was fairly well graded, it was necessary to mix two sands in approximately equal proportions. This was done while they were being screened to remove twigs and other undesirable matter. The mechanical analyses of the original sands and the graded combination are given in Table 42, and the analysis of the fluxed native asphalt, B, is the same as given in Table 41.

The bituminous sand was prepared by mixing heated sand and asphalt on a mixing board with rakes and shovels. A heater having about 90 square feet of heating surface was improvised to bring the temperature of the sand up to from 350° F. to 400° F. and two 1-barrel asphalt kettles were used to heat the bitumen to 300° F.

Beginning at the south end of the section for the first 52 linear feet the sand and asphalt are mixed in the proportions of 10 cubic feet of sand to 10 gallons of asphalt; in the next 27 linear feet the proportions are 10 cubic feet of sand to 11 gallons of asphalt; and in the remaining 3 linear feet the surface consists of a mixture of 10 cubic feet of sand No. 1 to 11 gallons of asphalt. The sand-asphalt mixture was spread 2½ inches thick and was held in place with 2 by 4 inch timber while it was being rolled with a 6-ton tandem roller.

The work was interrupted by a succession of showers. The section was so short that an organization of competent labor could not be perfected and the equipment was of the crudest kind.

The cost of constructing this section was disproportionately high and can not be fairly compared with that of producing the other sections of the series. Neither is it a just criterion of the cost of building a sand-asphalt pavement. Hence the cost data are not given.

TABLE 42.—*Mechanical analyses of sands used in experiment No. 8, West Palm Beach, Fla.*

	No. 1.	No. 2.	Mixed.
	Per cent.	*Per cent.*	*Per cent.*
Retained on 10-mesh sieve	0.0	0.1	0.1
Retained on 20-mesh sieve	.3	.4	.2
Retained on 30-mesh sieve	4.2	1.2	2.3
Retained on 40-mesh sieve	23.9	3.5	11.4
Retained on 50-mesh sieve	31.2	5.2	16.4
Retained on 80-mesh sieve	36.9	36.9	36.4
Retained on 100-mesh sieve	2.4	21.5	15.4
Retained on 200-mesh sieve	1.0	29.5	17.2
Passing 200-mesh sieve	.1	1.6	.6
Total	100.0	100.0	100.0

COST DATA.

This pavement was inspected in December, 1915. It had grown slightly wavy under traffic, but had not failed in any other respect. No difference in behavior or surface appearance was noticeable in the three subdivisions of the section.

EXPERIMENTS AT OCALA, FLA.

OIL-LIMESTONE, SAND-ASPHALT.

Among the road materials locally available in Marion County are sand-clay, a fairly well-graded sand, and easily crumbled oolitic limestone, which hardens somewhat on exposure to the air. It is apparently similar in character to but much softer than the coralline rock used in the Miami and West Palm Beach experiments. In 1915 an object-lesson road was constructed of sand-clay near Ocala, and on completion of this it was decided to construct experimental sections adjacent to the sand-clay road, utilizing the limestone and sand with bituminous materials. The series was installed in the spring of 1915 on the Ocala-Blichton road, about 3½ miles west of Ocala. Limestone for the oil-limestone experiment was obtained from a deposit which outcropped about 1 mile from the road. It was quarried with the use of dynamite and heavy sledges and in this way was easily broken to the desired size. For the surface course of the oil-limestone experiment the limestone was screened at the quarry over a ½-inch screen, yielding approximately 50 per cent retained on a ½-inch screen and passing a 3-inch screen. A suitable quality of sand for the sand-asphalt experiment was located about two-fifths of a mile from the road.

The equipment consisted of 2 sirup-heating kettles of 200 and 80 gallons capacity, which were set in a stone furnace and heated with wood fuel; a concrete mixer equipped with revolving blades and operated by a 4-horsepower gasoline motor; dump wagons; a 6-ton steam tandem roller; 2 hand rollers; corrugated culvert pipe for heating sand; hand pouring pots; and hand tools.

EXPERIMENT NO. 1.—LIMESTONE, RESIDUAL ASPHALTIC PETROLEUM, PENETRATION METHOD.

Location: Station 201+15 to station 212+92.
Length: 1,177 feet.
Area: 1,834 square yards.

Details.—Upon the rolled subgrade, partly of sand-clay and partly of sand, a foundation course of pit-run limestone was spread and rolled until firm. The depth of the foundation course was 5 inches, loose measurement. Upon this a wearing course, 2 inches thick by loose measurement of screened rock was spread and rolled with the 6-ton tandem roller sufficiently to smooth and shape the course but not to break up the fragments. Upon the wearing course was applied approximately 1 gallon per square yard of the residual asphaltic petroleum, analysis of which is given in Table 43. The petroleum was heated in the large sirup kettle at the roadside and was spread by means of hand-pouring pots. In applying the hot oil care was taken to coat the rock as uniformly and completely as was possible. The oil was immediately covered with sand and the surface was then rolled until firm. As the oil was forced upward through the sand by rolling, more sand was distributed to absorb it. Shoulders, 2 feet wide and 6 inches thick, of pit-run rock or screenings, were constructed on each side of the 14-foot oil-treated road. Materials and cost data for this experiment are given in Table 46.

TABLE 43.—*Analysis of residual asphaltic petroleum used in experiment No. 1.*

Specific gravity 25°/25° C	0.985
Viscosity, Engler, 100° C., 50 cc., specific	15.6
Float test at 32° C. (time)	1′ 48″
Float test at 50° C. (time)	0′ 40″
Loss, 163° C., 5 hours, 20 grams, per cent	1.64
Float test of residue[1] at 32° C. (time)	6′ 30″
Float test of residue at 50° C. (time)	1′ 30″
Per cent of total bitumen insoluble in 86° B. naphtha	17.98
Fixed carbon, per cent	10.04
Soluble in CS_2 (total bitumen), per cent	99.93
Organic matter insoluble, per cent	.07
Inorganic matter insoluble, per cent	.00
Total, per cent	100.00

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[1] Very viscous, sticky fluid.

EXPERIMENT No. 2.—SAND-OIL ASPHALT.

Location: Station 212+92 to station 220+85.
Length: 793 feet.
Area: 1,233.56 square yards.

Details.—The subgrade on the east end of this experiment, from station 212+92 to station 217+30, was an old sand-clay road, and in general provided a firm foundation. On this section the subgrade was dressed and rolled and the sand-asphalt mixture laid 2½ inches thick after compression. The subgrade from station 217+30 to station 220+85 consisted of fine sand, and the wearing course in this section is 3½ inches thick, laid in one course from station 217+30 to station 219+00, and in two courses, each roughly 1¾ inches thick from station 219+00 to station 220+85. Difficulty in securing a satisfactory bond between the two courses was experienced, owing to the fine sand distributed over the surface by laborers who walked over the first course. The sand subgrade was rolled with the 6-ton tandem roller, but as this left it much rougher than desired it was smoothed with hand rollers immediately in advance of spreading the mixture.

The heating and mixing operations were carried on about two-fifths of a mile from the road, where a clean, well-graded sand was found in abundance. All the sand was screened to remove twigs and roots, and also to reduce it to a finely divided condition, which undoubtedly facilitated heating. It was piled over 15-inch corrugated culvert pipes for heating, and stirred occasionally. This method of heating was found to be costly and relatively inefficient, and lack of heated sand limited the daily output of the mixer to much less than half of its normal capacity. The mixer, which was provided with revolving blades, was operated by a 4-horsepower gasoline motor, and was placed on an elevated platform, so that it could be emptied directly into a chute above the wagons. For each batch 6 cubic feet of heated sand was carried from the heating pipes to the charging platform in wheelbarrows, each carrying 2 cubic feet. After stirring the sand to avoid local overheating, oil-asphalt represented by the analysis given in Table 44 was added in an amount equal to about 10 per cent of the total weight, and the mixing was continued until all particles were thoroughly and uniformly coated with bitumen. The hot mixture was hauled to the road and, from dumping boards laid on the shoulder, was spread with shovels and hot rakes to the required thickness. The forms consisted of timbers placed along each side of the road at the proper grade. As soon as spread, the mix was rolled longitudinally and transversely with hand rollers, and after standing for some time, was covered with a light application of Portland cement, and rolled with the 6-ton tandem roller. The timbers were then removed and limestone shoulders, 6 inches thick and 2 feet wide, compacted by rolling, were constructed to support the sand-asphalt surface. Table 45 gives typical analyses of the sand-asphalt mixture. The data relating to materials and cost, given in Table 47, do not differentiate between the various sections, but are presented just as if the cost were uniform over the entire experiment, irrespective of the varying thickness of the wearing surface.

TABLE 44.—*Analysis of oil-asphalt [1] used in experiment No. 2.*

Specific gravity 25°/25° C.	1.041
Melting point ° C.	64
Penetration, 25° C., 100 grams, 5 seconds	50
Loss, 5 hours, 163° C., 20 grams, per cent	0.06
Penetration of residue [1] as above	38
Per cent of total bitumen insoluble in 86° B. naphtha	29.45
Fixed carbon, per cent	17.50
Soluble in CS_2 (total bitumen), per cent	99.86
Organic matter insoluble, per cent	.10
Inorganic matter insoluble, per cent	.04
Total, per cent	100.00

[1] Hard, sticky, glossy, semisolid.

TABLE 45.—*Typical analyses of sand-asphalt mixtures used in experiment No. 2.*

	I.	II.	III.	IV.	V.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bitumen (soluble in CS_2)	8.41	8.27	9.87	8.16	10.28
Mineral aggregate:					
Retained on 10-mesh sieve	0.1	0.0	0.1	0.0	0.1
Passing 10-mesh sieve, retained on 20-mesh sieve.	1.6	2.5	1.4	1.1	1.5
Passing 20-mesh sieve, retained on 30-mesh sieve.	4.9	4.7	5.1	4.7	4.3
Passing 30-mesh sieve, retained on 40-mesh sieve.	10.8	10.4	10.9	9.4	7.1
Passing 40-mesh sieve, retained on 50-mesh sieve.	13.1	12.3	13.5	13.7	16.0
Passing 50-mesh sieve, retained on 80-mesh sieve.	31.7	32.3	33.3	33.0	33.4
Passing 80-mesh sieve, retained on 100-mesh sieve.	12.9	11.8	12.5	12.1	12.4
Passing 100-mesh sieve, retained on 200-mesh sieve	15.7	19.7	14.2	12.0	18.4
Passing 200-mesh sieve	9.2	7.2	9.0	14.0	6.9
Average percentage of bitumen (soluble in CS_2)		9.25			

The cost data given in Tables 46 and 47 are based on the following scale of wages and unit prices:

Foreman, per 10-hour day, $3.25.
Subforeman, per 10-hour day, $1.25.
Skilled labor, per 10-hour day, $1.75.
Common labor, per 10-hour day, $1.
Teams, per 10-hour day, $3.
Asphaltic oil, f. o. b. Baltimore, Md., per gallon, $0.06.
Oil-asphalt, f. o. b. Baltimore, Md., per ton, $12.50.
Freight on oil-asphalt, Baltimore, Md., to Ocala, Fla., per ton, $6.72.

TABLE 46.—*Cost data, bituminous limestone.*

Item.	Total cost.	Cost per square yard of surface.	Item.	Total cost.	Cost per square yard of surface.
Rough grading	$45.15	$0.0247	Freight on oil	$57.44	$0.0313
Subgrade	48.82	.0266	Hauling oil to road	8.80	.0048
Shoulders	77.84	.0424	Heating and applying oil	24.52	.0133
Quarrying, labor	86.84	.0473	Hauling, screening, and spreading sand	8.80	.0048
Quarrying, explosives	51.31	.0280	Rolling (including cost of coal)	47.56	.0258
Loading and hauling	179.80	.0980	Incidentals and supervision	52.41	.0286
Spreading base course	10.00	.0055			
Screening limestone for wearing course	42.05	.0230	Total cost	858.05	.4674
Spreading wearing course	8.65	.0047	Total (exclusive of shoulders)	780.21	.425
Asphaltic oil, 1,801 gallons, f. o. b. Baltimore, Md	108.06	.059			

TABLE 47.—*Cost data, sand-asphalt.*

Item.	Total cost.	Cost per square yard of surface.	Item.	Total cost.	Cost per square yard of surface.
Rough grading	$34.80	$0.0282	Spreading mixture	$39.56	$0.0320
Subgrade	25.01	.0203	Hand rolling	5.45	.0044
Shoulders	119.60	.0969	Power rolling		.0168
				20.75	
Asphalt, 21.77 tons, including freight	418.70	.3393	Total cost	1,318.05	1.0681
Hauling asphalt (3¼ miles)	14.77	.0120	Total (exclusive of shoulders)	1,198.45	.9712
Screening and heating sand	310.00	.2512	Total (exclusive of rough grading and shoulders)	1,163.65	.9430
Heating asphalt	67.02	.0543			
Mixing sand and asphalt	192.09	.1557			
Transporting mixture	70.30	.0570			

SUPPLEMENTARY REPORTS ON EXPERIMENTS PREVIOUSLY REPORTED.

The experiments which were in progress at the beginning of the year have all been described in previous publications of the Office, and reference is made to these publications by number, in the descriptions below. It will be noted that the experiments undertaken at New York, N. Y., and Ridgewood, N. J., in 1910; at Boise, Idaho, in 1910, and at Newton, Mass., in 1908, have all been discontinued. As explained in Department Bulletin No. 257, the reasons for discontinuing these experiments were either that they have proved failures or that subsequent improvements have destroyed their value from the standpoint of furnishing comparable results.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT LEMON CITY, FLA., 1914.

OILS, TAR PREPARATION, CALCIUM CHLORIDE-CORALLINE ROCK.

The original report of the details of construction of these experimental sections was published in U. S. Department of Agriculture Bulletin No. 257.

In July, 1915, a surface treatment of asphaltic material was applied uniformly to all the sections by the county road authorities. The depression 55 feet from the south end of section 5, reported in Bulletin No. 257, was still noticeable, but had not increased in size appreciably. A few minor repairs had been made by using a mixture of sand and oil and the surface was in very good condition.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT WEST PALM BEACH, FLA., 1914.

OIL, TAR, OIL-ASPHALT, CORALLINE ROCK.

These experimental sections were constructed on the Miami-Quebec Highway, about 2 miles south of West Palm Beach, in May, 1914. The original report giving the details of materials and methods is published in U. S. Department of Agriculture Bulletin No. 257. As shown in Table 9 in that report, the traffic over this road is heavy suburban and the test of the various sections is therefore rather severe.

The work was inspected December 10, 1915, and the condition of the sections at that time was as follows:

Experiment No. 1. (*Residual asphaltic petroleum, 2.3 gallons. Penetration method.*)—This section is in very satisfactory condition. The bituminous material is still viscous, but the exudation and flow of the excess has ceased and the inequalities in the surface resulting from this flow are not sufficient to cause discomfort to traffic. There is no evidence of weakness developing at any point.

Experiment No. 2. (*Refined coal tars, 1.3 gallons. Penetration method.*)—The bituminous material has continued to harden and the surface is becoming pitted, owing to the fact that individual rocks have been broken and worked out of their setting. These pits are small and uniformly distributed and do not cause noticeable vibration in passing vehicles. About 25 feet from the south end of the section a shallow depression has formed. It is due apparently to settling of the pavement and not to wear.

Experiment No. 3. (*Refined coal tars, 1.2 gallons. Penetration method.*)—The proportion of rock exposed in the surface by the removal of the binder under traffic has increased visibly in the past year. These exposed rocks have worn lower than the surrounding areas still coated with tar and the surface is full of small shallow pits. The tar has become very hard and brittle.

Experiment No. 4. (*Residual asphaltic petroleum, 1.4 gallons. Penetration method.*)—The surface is in good condition, but is becoming slightly rough, due to pits where the rock is exposed. The difference in appearance between the part of the section treated with sand and that treated with stone chips is becoming more pronounced.

Experiment No. 5. (*Oil-asphalt, 1.8 gallons. Penetration method.*)—This section has changed little in appearance or condition and has resisted the action of traffic very satisfactorily.

Experiment No. 6. (*Oil-asphalt, 1.5 gallons. Penetration method.*)—The surface of this section is in perfect condition. While the asphalt has gradually hardened it has not lost its recementing power and is very efficacious as a binder.

Experiment No. 7. (*Coralline rock-waterbound macadam.*)—The surface of this section has worn down uniformly over the entire cross section and is nearly 2 inches below the surface of section No. 6, which it adjoins.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT MIAMI, FLA., 1913.

OIL-CORALLINE ROCK.

The original report of these experiments appeared in U. S. Department of Agriculture Bulletin No. 105 and the statement of their condition in January, 1915, was published in U. S. Department Bulletin No. 257. By that time it had become evident that experiments Nos. 1 and 2 were not successful and they were dropped from the record. The remaining experiments were inspected December 11, 1915, and their condition at that time was as follows:

Experiment No. 3. (*Penetration method. 0.6 gallon hot heavy oil.*)—The surface appearance of this section has not changed noticeably in the past year, except for the gradual exposure of a few particles of coralline rock under traffic. The slight inequalities in the surface reported last year remain unchanged. There were no breaks or seriously worn or weak spots.

Experiment No. 4. (*Penetration method. 0.7 gallon cold light oil.*)—This section, which last year had developed only a few worn depressions, is deteriorating rapidly. The binder has become brittle and the tendency of the rock particles to break away and form holes has become general over the entire area. Repairs made with rock only have failed under traffic, but those in which asphaltic material were added have worn satisfactorily.

Experiment No. 5. (*Penetration method. 0.6 gallon hot heavy oil.*)—The worn depressions and holes reported last year have increased greatly in size and number. The bituminous material has lost its cohesive power and is crumbling. Repairs have been made with coralline rock without bituminous material. It is probable that the entire section will be reconstructed during the coming year.

Experiment No. 6. (*Penetration method. 1.0 gallon hot heavy oil.*)—This section is in excellent condition and shows no signs of local failure or undue wear at any point. It is probable that no repairs will be required during the ensuing year.

SUPPLEMENTARY REPORT OF EXPERIMENTS ON ROCKVILLE PIKE, MONTGOMERY COUNTY, MD., 1913.

The original report of these experiments was given in U. S. Department of Agriculture Bulletin No. 105, and report of the first inspection appeared in Bulletin No. 257. The following information covers the history of the experiments up to February 28, 1916:

Experiment No. 1.—Refined Coal Tar, Hot Application.

As expected at the time of the last report, this experiment required re-treatment during the summer of 1915. The work was done between July 12 and 23, using the same bituminous material as in the original treatment. The tar was delivered directly from the stills of the manufacturer in tank wagons, from which it was distributed under steam pressure at a temperature of 165° to 200° F. A nozzle delivering a conical spray was used and steam was furnished by a road roller which also drew the tank wagon. Since unskilled labor only was available, considerable difficulty was experienced in getting uniform distribution. Clean, washed gravel passing a $\frac{5}{8}$-inch mesh was used as covering material over the entire experiment, as it is considered no longer warrantable to continue the use of trap rock on those sections where it was originally used. The characteristics of a typical sample of the bituminous material are here given, Table 48, and the cost data and quantities will be found in Table 55.

At the time of this re-treatment experiment No. 1 was extended northward from station 61+20 to the forks of the road at station 90+75, thus adding 2,955 feet to experiment No. 1 and reducing the length of experiment No. 2 by a like amount. The reason for this is explained later.

At the time of the inspection the surface was practically intact over the area of the original experiment. But owing to the unequal distribution of tar by the conical hand nozzle used, and the consequent rather large variation in the amount of covering material held by the bitumen, the road surface plainly shows a continuous series of arc-like curves. Some of these are little more than visible and produce no marked vibration as traffic passes, but much the greater part are developing as flat ridges, which are decidedly perceptible to the occupants of a vehicle passing rapidly along the road. From present indications the lower areas, where the mat is thinner, are going to wear rapidly, and the amount of repairing necessary will correspondingly increase.

TABLE 48.—*Analysis of refined coal tar used on experiment No. 1.*

Specific gravity 25°/25° C.		1.205
Float test at 32° C. (time)		1′ 48″
Float test at 50° C. (time)		0′ 46″
Per cent free carbon (insoluble in CS_2)		12.65
Distillation:	Per cent by vol.	Per cent by wt.
Water	0.0	0.0
First light oils (to 110° C)	[1] .5	.3
Second light oils (110° to 170° C.)	[2] .7	.5
Heavy oils (170° to 270° C.)	[3] 17.1	15.4
Heavy oils (270° to 315° C.)	[4] 13.7	11.8
Pitch residue	[5] 68.0	72.0
Total	100.0	100.0

Over the extended area of the experiment the surface is already broken in a great many places. Initial weaknesses, which developed over this section when a part of experiment No. 2, are persistent, and much patching has been necessary since a few weeks after the re-treatment in July. The failures are generally distributed over the surface and not confined to any strip. This section has an exceedingly heavy traffic, and during the winter is usually very dirty, owing to the bad condition of the lanes and adjacent roads which deliver traffic to the section.

The section of this experiment in Bradley Lane has been reconstructed as penetration macadam, and is described as a new experiment in another part of this publication.

EXPERIMENT NO. 2.—REFINED WATER-GAS TAR, COLD APPLICATION.

Those sections referred to in the last report, from Norwood trolley station to Edgewood station, as being poorly drained and under considerable strain, became so bad in the spring of 1915 that at the time of re-treating experiment No. 1 with a hot refined coal tar it was decided to extend the re-treatment northward to include the weak part of experiment No. 2.

That part of No. 2 remaining is now in first-class condition. The general failure, especially along the edges, that was so rapid in the early spring of 1914, had no counterpart in the spring of 1915, and during the winter of 1915–16 the experiment has remained in excellent condition. While there are no indications of general failure, the mat is becoming very thin, and it is planned to give a re-treatment during the summer of 1916. The section of this experiment in Bradley Lane has been reconstructed as a penetration macadam and is described as a new experiment in another part of this publication.

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[1] Solid. [2] Clear. [3] One-third solid. [4] One-fourth solid. [5] Hard, brittle.

EXPERIMENT NO. 3.—ASPHALTIC PETROLEUM, COLD APPLICATION

During the winter of 1914 the surface cracked and crumbled in places as during the preceding winter, and in many places mud formed. This ironed out under traffic, but the mat was so thin and broken that a second re-treatment became necessary and was applied June 25 to 30, 1915. A short section at the north end was not finished until August 16–18. The work was done by hand, as described in the last report, using the same bituminous material originally applied and torpedo sand similar to that used on experiment 7. Table 49 shows the characteristics of the bituminous material used, and cost data will be found at the end of this report.

TABLE 49.—*Analysis of asphaltic petroleum used on experiment 3.*

Specific gravity, 25°/25° C	0.932
Flash point, °C	35
Burning point, °C	70
Viscosity, Engler, 50 c. c., at 25° C., specific	61.9
Loss, 5 hours, at 163° C., 20 grams, per cent	22.94
Float test of residue at 32° C., time	5′ 53″
Float test of residue at 50° C., time	1′ 22″
Percentage of total bitumen insoluble in 86° B. naphtha	13.67
Fixed carbon, per cent	7.62
Soluble in CS_2 (total bitumen), per cent	99.90
Organic matter insoluble, per cent	.10
Inorganic matter insoluble, per cent	.00
Total, per cent	100.00

This experiment is becoming rough on one hill, where frequent unusual repairs have had to be made, as described in an earlier report. Except for this the surface presents the same characteristics as it did a year ago. During cold weather the mat crumbles rather freely and at the first thaw mud is formed. If traffic is not too heavy and the mud is not displaced the surface mat is restored rapidly as the surface dries and generally assumes its corky nature. If the mud is displaced to any marked degree, as is very likely to happen if there is a snow storm followed by a thaw, then the mat is not restored along the wheel tracks and two broad, shallow ruts are the result. The stone is soon exposed along these ruts and disintegration follows rapidly. At the time of inspection ruts had formed along about 200 feet of this experiment at the same point where they formed in the winter of 1914–15.

It is planned to give this experiment a fourth application early in the season of 1916. Except as noted above, the surface is smooth and in essentially as good condition as at the time of construction.

EXPERIMENT NO. 4.—RESIDUAL ASPHALTIC PETROLEUM, HOT APPLICATION.

This experiment continues to present the best appearance of any of those still carrying the original treatment. No re-treatment was necessary during 1915, but it is probable that one will be required during the coming summer. The surface has not become so muddy at any time during the winter of 1915–16 as during that of 1914–15. The bumps due to faulty distribution at the time of original treatment are still visible and cause considerable trouble. They have been repeatedly cut and trimmed, but owing to the excess of bituminous material the spots have required top dressing in the hottest weather, and this builds them up again. There has been considerable repair work necessary over all of the experiment, but no place shows marked weakness. Patches made on this experiment are unusually smooth and serviceable, and so far there appears no tendency for the original surface to break or give way around patches.

Experiment No. 5.—Residual Asphaltic Petroleum, Hot Application.

This experiment, like No. 4, shows less tendency to become muddy during thaws, although dampness of subgrade continues to be very noticeable. During the past summer a great deal of patching has been necessary and the breaks have been somewhat more numerous in the bottoms and poorly drained sections than elsewhere, although they have been general. It is now expected that the experiment will require re-treatment during the coming season.

Experiment No. 6.—Water-Gas Tar Preparation, Hot Application.

This experiment required but little attention during 1914, but early in the spring of 1915 it began to break up rather rapidly. The nature of the failure was very similar to that described for experiment No. 2 in 1914. Breaks in the mat at the sides of the road progressed rapidly toward the center and any raw edge of the mat had a tendency to crumble away rapidly. It was always necessary to give immediate attention to patching, and even with care in some instances patches had to be made that extended from the sides nearly to the center of the road and were from 4 to 6 feet long. It finally became necessary to re-treat November 8 to 12. The work was done by contract, using the same type of bituminous material as originally applied and covering with clean, washed gravel passing a $\frac{5}{8}$-inch screen. The contract price was $1,170 or 11.1 cents per square yard. The characteristics of the material used are shown in Table 50 and additional data are given at the end of this report.

Table No. 50.—*Analysis of water-gas tar preparation used on experiment No. 6.*

Specific gravity 25°/25° C.	1.136
Float test at 32° C., time	2′ 11″
Free carbon (insoluble in CS_2), per cent	1.71

Distillation:	Per cent by vol.	Per cent by wt.
Water	0.0	0.0
First light oils (to 110° C.)	0.0	0.0
Second light oils (110° to 170° C.)	0.0	0.0
Heavy oils (170° to 270° C.)	[1] 10.9	8.7
Heavy oils (270° to 315° C.)	[2] 11.4	10.4
Pitch residue	[3] 77.7	80.9
Total	100.0	100.0

The covering was applied somewhat too heavily. This was in a measure due to a desire to prevent excessive bleeding in the spring. Reference to the preceding report will show that the original treatment bled very freely, and already, at the date of inspection (Feb. 28) the re-treated surface became sticky on sunny days. Material is now distributed along the road ready for use at the first indication of stickiness. The surface is in excellent condition now, fully as good as when originally built, and at the date of inspection there was not a break in it.

EXPERIMENT NO. 7.—ASPHALTIC PETROLEUM, COLD APPLICATION.

Reference to the last report will show that this experiment was showing signs of weakness in the fall of 1914. It should have been re-treated at that time, as conditions in the spring of 1915 have since clearly shown. The mat was quite generally forced aside or carried away along two broad, shallow ruts when the surface became muddy in the late winter of 1914–15, and in many places the road metal began to ravel. These ruts were from 18 inches to 2 feet wide and frequently the entire hand could be slipped under a straight edge laid across the rut. A very large amount of patching was necessary to put the experiment into condition for a re-treatment. The re-treatment was given June 21 to 23, 1915, using the same bituminous material as in the original re-treatment (Table 51), and covering with torpedo sand, represented by the analysis given in Table 52. The quantities and costs are given in Tables 54 and 55.

At the time of the inspection this experiment was in excellent condition, except on one or two very short sections where the rutting was excessive last spring. The re-treatment application was very light and there appears to be no noticeable accumulation of mat. The experiment will probably require re-treatment late in the summer of 1916.

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[1] Clear.

[2] Clear; showed 10.0 per cent insoluble in dimethyl sulphate.

[3] Hard, glossy. A 315°–350° C. fraction showed 12.5 per cent insoluble in dimethyl sulphate.

TABLE 51.—*Analysis of asphaltic petroleum used on experiment No. 7.*

Specific gravity 25°/25° C	0.958
Flash point, °C	32
Burning point, °C	81
Viscosity, Engler, 25° C., 50 cc. specific	96.8
Loss 5 hrs. at 163° C. 20 grams, per cent	25.57
Float test on residue at 50° C., time	1′ 13″
Per cent of total bitumen insoluble in 86° C. naphtha	5.38
Fixed carbon, per cent	3.60
Soluble in CS_2 (total bitumen), per cent	99.90
Organic matter insoluble, per cent	.08
Inorganic matter insoluble, per cent	.02
Total, per cent	100.00

TABLE 52.—*Mechanical analysis of sand used on experiment No. 7.*

	Per cent.
Passing ¼-inch screen, retained on ⅛-inch screen	10.6
Passing ⅛-inch screen, retained on 10-mesh sieve	5.3
Passing 10-mesh sieve, retained on 20-mesh sieve	10.8
Passing 20-mesh sieve, retained on 30-mesh sieve	9.8
Passing 30-mesh sieve, retained on 40-mesh sieve	13.3
Passing 40-mesh sieve, retained on 50-mesh sieve	12.1
Passing 50-mesh sieve, retained on 80-mesh sieve	20.5
Passing 80-mesh sieve, retained on 100-mesh sieve	5.3
Passing 100-mesh sieve, retained on 200-mesh sieve	2.9
Passing 200-mesh sieve	9.4
Total	100.0

The traffic census has been continued, regular counts being taken every 13 days. The point of observation was changed on June 26, 1915, so as to give better control, and the period of observation was reduced to 16 hours. A tabulation of the maximum and average of each class of traffic for the period between June 26, 1915, and February 28, 1916, is given in Table 53. Traffic south of the census station is on experiment No. 1, that north of the station is on experiments Nos. 2 to 7, inclusive.

TABLE 53.—*Volume and character of traffic on Rockville Pike at the north end of section 1.*

Vehicle.	Sections 2 to 7.				Section 1.			
	Maximum.		Average.		Maximum.		Average.	
	North-bound.	South-bound.	North-bound.	South-bound.	North-bound.	South-bound.	North-bound.	South-bound.
Loaded 1-horse wagon	18	9	8	4	30	13	16	8
Unloaded 1-horse wagon	9	16	5	8	18	27	8	15
Loaded 2-horse wagon	22	16	7	6	59	24	25	11
Unloaded 2-horse wagon	10	22	3	5	15	44	5	17
Loaded 4-horse wagon	1	3	....	1	2	7	....	2
Unloaded 4-horse wagon	3	3	....	....	6	2	1	....
1-horse pleasure vehicle	14	15	6	6	30	28	15	15
2-horse pleasure vehicle	1	2	....	....	1	2	....	....
Saddle horse	19	7	4	4	18	25	7	7
Motor cycle	48	78	16	17	55	71	22	21
Excessively heavy vehicle	2	2	....	....	14	5	2	....
Motor runabout	74	90	24	26	88	104	35	37
Motor touring car	381	528	117	126	442	582	163	169
Loaded motor dray	26	26	15	16	63	43	31	25
Unloaded motor dray	10	13	3	6	17	48	7	15

Tables 54 and 55 show comparative cost data to date for the various experiments included in this project.

TABLE 54.—*Surface maintenance costs of 1913 experiments on Rockville Pike, Montgomery County, Md., to December 31, 1915.*

Experiment No.	Bituminous material.	Date completed.	Length.	Total cost[1] per square yard prior to Jan. 1, 1915.	Surface[2] maintenance per square yard during 1915.	Total cost of surface per square yard to Dec. 31, 1915.	Surface maintenance per mile per year 1915.	Total maintenance per mile for 1 year.
		1913.	*Feet.*	*Cents.*	*Cents.*			
1	Refined coal tar (hot)......	Sept. 22	9,060	12.34	15.36	$27.70	$1,129.90	$1,486.49
2	Refined water-gas tar (cold)................	Sept. 24	4,425	9.55	9.34	18.89	137.81	202.22
3	Asphaltic petroleum (cold)................	Sept. 30	7,400	9.05	11.37	20.42	401.20	529.25
4	Residual asphaltic petroleum (hot).........	Oct. 15	7,100	11.28	3.93	15.21	170.20	276.73
5	.....do................	Nov. 21	6,775	11.30	4.02	15.32	141.78	226.68
6	Water-gas tar preparation (hot)............	Nov. 26	6,325	11.71	15.82	27.53	1,200.48	1,270.93
7	Asphaltic petroleum (cold)................	Dec. 5	6,689	10.03	10.38	20.41	828.84	894.24

[1] Average for trap and gravel.

[2] To December 31, 1915.

TABLE 55.—*Materials and cost data for surface retreatments in 1915 on Rockville Pike, 1913 project.*

Section No.	Bituminous material.	Area of section.	Quantity of material per square yard.			Cost per square yard (cents).	
			Bituminous material.	Gravel.	Sand.	Bituminous material.	Gravel.
		Sq. ft.	*Gallons.*	*Cu. yds.*	*Cu. yd.*		
1	Refined coal tar, hot application.....	15,000	0.425	0.014	....	0.038	0.043
3	Asphaltic petroleum, cold application	7,400	.165	....	0.016	.014	....
6	Water-gas tar preparation, hot application..............................	10,542	.474	.018	....	....	....
7	Asphaltic petroleum..................	11,148	.204	....	.011	.022	....

Section No.	Bituminous material.	Cost per square yard (cents).					
		Sand.	Cleaning surface.	Applying bituminous material.	Applying sand or gravel.	Supervision.	Total.
1	Refined coal tar, hot application.....	....	0.003	0.007	0.015	0.003	0.109
3	Asphaltic petroleum, cold application	0.036	.002	.008	.005	.005	.070
6	Water-gas tar preparation, hot application..............................	....	....	....	....	....	[1] .111
7	Asphaltic petroleum..................	.023	.001	.006	.004	.002	.058

[1] Work done by contract.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT WASHINGTON, D. C., 1912.

TAR PREPARATION AND OILS, SURFACE TREATMENT.

The original report of these experiments was published in Circular No. 99 of the Office of Public Roads, and inspection reports have appeared in United States Department of Agriculture Bulletins Nos. 105 and 257. The following report describes the condition of the pavement before re-treatment, the extent of the repairs during 1915, and the condition of the experiments when inspected on February 25, 1916.

SECTION NO. 1.—REFINED WATER-GAS TAR PREPARATION.

Section 1 appeared intact and required neither repairs nor re-treatment during the summer of 1915.

Section 2 raveled locally in some spots to a depth of 2 inches or more. Most of these failures were along the wheel tracks. Only one was at the edge, and this failure was probably due in some measure to defective drainage. The mat was worn unevenly, and over considerable areas was entirely gone. The entire section was repaired with penetration patches, in which an oil asphalt and limestone were used, top-dressed with trap chips.

The cost of patching was:

Labor	$9.50
Materials	8.10
Total	17.60=$0.0155 per square yard.

The section was then re-treated with the same materials originally used. An analysis of the asphaltic petroleum is given in Table 57.

SECTION NO. 3.—RESIDUAL PETROLEUM.

Section 3 had been persistently muddy during the last winter and spring. The oily mud had been forced aside from the prevailing wheel tracks, so that many bare places and depressions existed, and one long rut about 1½ inches deep and 8 to 10 inches wide had developed along the north edge for some 75 or 80 feet at the west end.

TABLE NO. 56.—*Cost of preliminary repairs per square yard.*

Section.	Labor.	Materials.	Total.
1			
2	$0.0084	$0.0071	$0.0155
3	.0109	.0073	.0182
4			

The section was first patched in the same manner as section 2 and then re-treated. To avoid, if possible, the marked deterioration of this section during the winter, the material used on section 4 was selected for this re-treatment, instead of the original material. The cost of repairs was:

Labor	$7.75
Materials	5.18
Total	12.93=$0.0182 per square yard.

SECTION No. 4.—ASPHALTIC PETROLEUM.

Section 4 remained in generally good condition. It required no preliminary repairs and was re-treated with the material originally used. An analysis of the bituminous material used on section 3 and 4 is given in Table 57.

TABLE 57.—*Analysis of asphaltic petroleums used on sections Nos. 2, 3, and 4, Washington, D. C., 1915.*

	Section 2.	Sections 3 and 4.
Specific gravity 25°/25° C	0.963	0.949
Flash point °C	31	30
Burning point °C	84	70
Viscosity at 25° C., 50 cc. Engler specific	128.4	94.8
Loss, 5 hrs. at 163° C., 20 grams, per cent	23.14	30.51
Float test on residue, 32° C. (time)	2′ 37″	4′ 35″
Float test on residue, 50° C. (time)	1′ 4″	1′ 23″
Percentage of total bitumen insoluble in 86° B. naphtha	5.96	14.03
Fixed carbon, per cent	4.62	7.70
Soluble in CS_2 (total bitumen), per cent	99.94	99.90
Organic matter insoluble in CS_2, per cent	0.04	0.05
Inorganic matter insoluble in CS_2, per cent	0.02	0.05
Total, per cent	100.00	100.00

TABLE 58.—*Quantities and costs of re-treatments per square yard.*

Section No.	Area.	Bitumen.	Sand.	Costs (materials).		
				Bitumen.	Sand.	Total materials.
	Sq. yds.	*Gallon.*	*Cu. yd.*	*Cent.*	*Cent.*	*Cent.*
2	1,129	0.044	0.003	0.0089	0.0044	0.0133
3	711	.229	.007	.0137	.0114	.0251
4	1,330	.150	.007	.0090	.0122	.0212

Section No.	Costs (labor).							
	Sweeping.	Pouring oil.	Brooming oil.	Spreading sand.	Hauling sand.	Superintendence.	Total labor.	Total costs.
	Cent.	*Cent.*	*Cent.*	*Cent.*	*Cent.*	*Cent.*	*Cent.*	*Cent.*
3	0.0018	0.0015	0.0039	0.0012	0.0039	0.0049	0.0172	0.0305
2	.0048	.0014	.0057	.0024	.0046	.0058	.0247	.0498
4	.0011	.0007	.0024	.0012	.0008	.0052	.0014	.0326

At the time of the inspection made on February 25, 1916, the condition was substantially as follows:

Section 1, which was not re-treated during the past season, appeared in no need of re-treatment.

Section 2 had become rough and uneven, owing both to settlement under traffic in extremely wet weather and to disintegration of the surface. One large hole had developed on the south side at a point where traffic entering from Fourteenth Street fails to turn closely enough to the north corner and in consequence shears away the south edge for several feet. This section has also a number of potholes and spots where the mat was entirely worn away. Extensive repairs will be necessary as soon as the weather permits.

Section 3 suffered as usual on account of seepage from the terrace that lies along the south side of the section. An effort was made to drain this section and a small part of section 2, but sufficient funds were not available to complete the work.

Section 4 has remained in excellent condition. Only one small area at the south end has required any attention. The break at this point was due to the impact of traffic passing from the asphalt driveway to the surface treatment.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD., 1912.

BITUMINOUS CONCRETE, CEMENT CONCRETE, OIL-CEMENT CONCRETE, VITRIFIED BRICK, BITUMINOUS SURFACE TREATMENTS ON CONCRETE.

The original report of these experiments was begun in Circular No. 99 of the Office of Public Roads and completed in U. S. Department of Agriculture Bulletin No. 105. Report of inspection made on March 14, 1915, was published in Department Bulletin No. 257. The following report covers the condition of experiments on February 28, 1916.

Experiment No. 1.—Bituminous Concrete, Topeka Specification.

The general appearance of the experiment is the same as at the last inspection. Imperfections then noted still exist in addition to those noted here. There is one bad break at the north side of the turn into Bradley Lane. Both surface and concrete gutter are broken and indicate some unusual blow. The depression noticed about midway of the section near the curb has increased in size and depth. A second cup-hole 200 feet north of Bradley Lane, near the east side of the road, and a third one, 60 feet from the north end of the limestone section, were noted. In the last 60 feet of this section, 10 or 12 slight imperfections appear. On the trap section a noticeably increasing waviness occurs along the gutter for a width of 2 to 2½ feet.

EXPERIMENT NO. 2.—BITUMINOUS CONCRETE, DISTRICT OF COLUMBIA SPECIFICATION.

This surface continues in essentially the same condition as when last reported. The same cracks were noted and in addition the surface is worn near the curb and gutter, but is generally firm and smooth even in these places. Small pits are to be found quite generally scattered over the south two-thirds of the limestone section. These decrease toward the north end. The expansion joint which was noted in the last report as having failed again buckled in the spring and early summer of 1915. The Portland cement concrete block, 1 foot wide and approximately 18 inches deep, which was put in at this joint was sheared horizontally by the stresses developed and the top 6 inches of the slab was lifted intact from the rest of the block. To repair this joint, all of the broken concrete of experiment No. 3 was removed. The crack limiting the area of failure was from 2 to 4 feet back of the expansion joint. This entire section was re-laid with concrete similar to the original experiment, with a 2½-inch joint left for expansion. This joint was filled with heavy oil puddled with sand.

EXPERIMENT NO. 3.—CEMENT CONCRETE AND OIL-CEMENT CONCRETE; SURFACES TREATED WITH BITUMINOUS MATERIALS.

The surfaces of this experiment have been permitted to wear without repairs and the condition of the various sections at the time of inspection was noted as follows:

(A) *Refined coal tar.*—Twenty to 25 per cent of the surface treatment has worn off this section. The side toward the gutter shows considerably more exposed concrete than the other side.

(B) *Water-gas tar preparation No. 2.*—This area continues slightly better than A, but is deteriorating more rapidly now than during last year.

(C) *Fluxed native asphalt No. 2.*—Eighty-five per cent of the mat is gone on the west half and about 1 per cent on the east half.

(D) *Fluxed native asphalt No. 2 over water-gas tar preparation No. 1.*—About 85 per cent of this treatment has disappeared from the west half and about 5 per cent from the east half.

(E) *Fluxed native asphalt over native asphalt emulsion.*—About 85 per cent of this area is bare on the west half of the road and about 10 per cent on the east half.

(F) *Oil asphalt No. 1 over water-gas tar preparation No. 1.*—A few scattered patches only of the surface treatment remained.

(G) *Refined coal tar.*—The surface treatment is worn off to a great extent over the entire section.

(H) *Water-gas tar preparation No. 2.*—Seventy-five per cent of the surface is worn off from the west half but the east half remains almost intact.

(I) *Fluxed native asphalt No. 2.*—About 60 per cent of the treatment is gone from the west half but the east half remains almost intact.

(J) *Oil asphalt No. 2.*—About 35 per cent of the surface treatment is gone from the west quarter of the road. The remainder is almost intact.

EXPERIMENT NO. 4 (OIL-CEMENT CONCRETE) AND EXPERIMENT NO. 5 (CEMENT CONCRETE).

During the interval of another year there appears to have developed a slight difference in the wearing of the two classes of concrete. On the gravel, limestone, and trap sections, the oil-cement appears to have worn a little more than the cement concrete. The trap section especially has become much rougher for a width of 2 feet along the gutter. The marked difference in the wear on the east and west sides is perhaps more noticeable than at last inspection.

EXPERIMENT NO. 6.—VITRIFIED BRICK.

There is no plainly visible difference in wear between the several sections of this experiment.

A traffic census has been taken on this road every thirteenth day for a 16-hour period. A tabulation of the maximum and average for each class of traffic from March 8, 1915, to February 22, 1916, is given in Table 59. The west side of the road carries south-bound traffic coming from the railroad and the east side carries north-bound traffic toward the railroad.

TABLE 59.—*Volume and character of traffic on Connecticut Avenue north and south of Bradley Lane and on Bradley Lane.*

Vehicle.	North.				South.				Bradley Lane.			
	Maximum.		Average.		Maximum.		Average.		Maximum.		Average.	
	East side.	West side.	East side.	West side.	East side.	West side.	East side.	West side.	East-bound.	West-bound.	East-bound.	West-bound.
Loaded 1-horse wagon..	6	22	2	13	18	14	9	8	14	10	5	4
Unloaded 1-horse wagon	8	20	2	10	17	17	7	8	12	14	5	5
Loaded 2-horse wagon..	12	82	5	34	21	88	9	32	30	12	10	6
Unloaded 2-horse wagon	55	34	14	16	80	12	30	4	8	19	1	7
Loaded 4-horse wagon..	2	4	0	1	3	3	1	1	3	2	1	0
Unloaded 4-horse wagon	1	1	0	0	1	1	0	0	0	1	0	0
1-horse pleasure vehicle.	5	16	1	7	15	10	7	5	11	13	4	4
2-horse pleasure vehicle.	0	3	0	0	5	3	1	0	3	3	0	0
Rubber-tired horse vehicle................	0	0	0	1	1	0	0	0	0	0	0	0
Saddle horse...........	10	50	2	3	10	13	3	3	5	43	1	3
Motor cycle............	6	35	1	13	22	17	11	9	24	13	8	7
Excessively heavy vehicle................	1	9	0	1	5	5	1	1	2	3	0	1
Motor runabout........	22	136	4	59	171	120	70	47	67	66	25	28
Motor touring car......	84	589	10	211	546	502	242	169	300	264	85	95
Loaded motor dray....	32	81	2	34	53	39	30	23	22	29	13	16
Unloaded motor dray..	13	33	1	12	20	32	6	10	10	9	4	4

MAINTENANCE DURING 1915.

Repairs on these experiments, together with the total cost of each experiment to December 31, 1915, are shown in Table 60.

TABLE 60.—*Surface maintenance costs of 1912 experiments at Chevy Chase, Md., to December 31, 1915.*

Experiment No.	Date completed.	Area.	Maintenance cost of experiment.			Total cost per square yard (cents.)		
			Total for projects to Dec. 31, 1914.	1915	Total.	Construction.	Maintenance.	Total.
		Sq. yds.						
1	1912	1,498	....	$3.25	$3.25	186.62	0.22	186.84
2	...do....	1,400	$4.11	3.55	7.66	195.65	.55	196.20
3	Spring, 1913	2,837	1.03	2.54	3.57	[1] 142.12	.13	142.25
4	...do....	3,019	2.15	18.35	20.50	[1] 151.21	.68	151.89
5	...do....	3,013	2.07	20.66	22.73	[1] 143.13	.75	143.88
6	...do....	2,055	1.36	.41	1.77	258.21	.08	258.29

[1] Weighted average price for different aggregates.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT CHEVY CHASE, MD., 1911.

BITUMINOUS CONSTRUCTION AND SURFACE TREATMENT.

The original reports of these experiments are given in Circulars Nos. 98 and 99, Office of Public Roads, and supplementary reports appear in U. S. Department of Agriculture Bulletin No. 105, and again in Department Bulletin No. 257. The following report is based upon an inspection made February 28, 1916.

SECTION NO. 1.—REFINED COAL TAR, PENETRATION METHOD.

At the time of the inspection this experiment presented a surface almost intact, except at the narrowest part on the curve, where traffic is much concentrated. Here the mat is wearing off in sections. The experiment is becoming somewhat rough along the gutter on the west side, due probably to failure of the foundation. A similar condition is noticeable in many of the sections of this project.

SECTION NO. 2.—REFINED COAL TAR, MODIFIED GLADWELL METHOD.

The condition of this section continues about the same as when last inspected, except for a slightly increased roughness along the gutter edge.

SECTION NO. 3.—FLUXED NATIVE ASPHALT, PENETRATION METHOD.

Wear on this section continues along the line indicated last year. Those areas which were without mat at the time of the last inspection are quite generally marked with small pits which are adjacent to large particles of exposed aggregate.

SECTION NO. 4.—GILSONITE OIL-ASPHALT, PENETRATION METHOD.

The mat on this section is nearly gone and during the summer, especially on the north half of the experiment, heavy patching was necessary. From indications it is probable that similar heavy patching will be required on the south half during the coming season. Disintegration has appeared along the gutter, due to foundation failure. The mat is decidedly lacking in uniformity, but where the mat is gone the stone is generally well bonded and is wearing smooth, except along the gutters and near the south entrance to the Chevy Chase Club. At this latter point several areas of approximately 1 square foot each are a mass of small cracks, although the mat still covers the stone. These spots are probably evidence of foundation weakness.

SECTION NO. 5.—OIL-ASPHALT, PENETRATION METHOD.

On the east side of the car tracks this section is in generally good condition. The mat is becoming very thin, however, especially on that half of the road toward the gutter, and the stone is exposed over large areas; but the aggregate appears well bonded, and the exposed faces are wearing smooth without much tendency to ravel. On the west side, while the road is much more worn and has been heavily patched, especially toward the south end, it is now practically intact, although rough.

SECTION NO. 6.—OIL-ASPHALT, PENETRATION METHOD.

This experiment has the general appearance of section 5. The east side is worn somewhat more evenly than 5, and the stone is more generally exposed, but there is no tendency to ravel. A seal coat should be given in the spring. On the west side the surface is less uniform and is badly pitted and rough for about 50 feet along the gutter near the north end. This is probably due to foundation failure, as mentioned in other sections. The location of this experiment was such that at the extreme north end traffic passed over it in almost every possible direction. The main entrance to the Chevy Chase Club, a brick crossover on the suburban trolley tracks, the turnout to Bradley Lane, and the fact that from this point northward Kensington Road is surfaced on only one side, while to the south it is surfaced on both sides of the tracks, were conditions that brought such unusual traffic on the extreme end of this section as to wear it very seriously. The adjacent experiment and the brick crossover are much more resistant types of surface than the penetration experiment. This contrast is brought out by the fact that over an area of 12 to 15 square yards the penetration experiment was worn from 1 inch to 2½ inches below grade. During the past summer it became necessary to remedy this condition and it was done by scarifying a section about 40 feet long so as to include the entire Chevy Chase Club entrance, then using the scarified material as a base and laying a new wearing surface of bituminous concrete of the analysis given in Table 61. A sample of the fluxed native asphalt used in the mixture gave the analysis shown in Table 62. At the time of inspection this intersection was in perfect condition. The total area of the intersection, as rebuilt, was 100 square yards, and the work was done by contract at a cost of $150.

TABLE 61.—*Analysis of bituminous concrete used in resurfacing a portion of section 6.*

	Per cent.
Bitumen soluble in CS_2 (total bitumen)	9.5
Mineral aggregate passing ¾-inch screen, retained on ½-inch screen	2.0
Mineral aggregate passing ½-inch screen, retained on ¼-inch screen	11.0
Mineral aggregate passing ¼-inch screen, retained on ⅛-inch screen	15.3
Mineral aggregate passing ⅛-inch screen, retained on 10-mesh sieve	5.6
Mineral aggregate passing 10-mesh sieve, retained on 20-mesh sieve	14.1
Mineral aggregate passing 20-mesh sieve, retained on 30-mesh sieve	9.7
Mineral aggregate passing 30-mesh sieve, retained on 40-mesh sieve	9.3
Mineral aggregate passing 40-mesh sieve, retained on 50-mesh sieve	7.4
Mineral aggregate passing 50-mesh sieve, retained on 80-mesh sieve	11.5
Mineral aggregate passing 80-mesh sieve, retained on 100-mesh sieve	2.8
Mineral aggregate passing 100-mesh sieve, retained on 200-mesh sieve	3.7
Mineral aggregate passing 200-mesh sieve	7.6
Total	100.0

TABLE 62.—*Analysis of fluxed native asphalt used in bituminous concrete, section 6.*

Specific gravity, 25°/25° C	1.070
Melting point, °C	55
Penetration 25° C. 100 grams. 5 seconds	50
Loss at 163° C. 5 hours, 20 grams, per cent	2.51
Penetration of residue as above	22
Per cent of total bitumen insoluble in 86° B naphtha	26.72
Fixed carbon, per cent	12.52
Soluble in CS_2 (total bitumen), per cent	94.85
Organic matter insoluble in CS_2, per cent	1.80
Inorganic matter insoluble in CS_2, per cent	3.35
Total, per cent	100.00

SECTION NO. 7, A AND B.—OIL-ASPHALT, PENETRATION METHOD.

Section A is much more distinctly mosaic than B and a little smoother. It has a few potholes and will probably require a seal coat in the spring. The south half of B still retains the mat fairly intact, but it appears to be worn very thin. The surface is full of short, irregular waves, especially on the north half, where there are many bare places and a few potholes. Where cleaned the surface shows a somewhat mosaic appearance and toward the north end becomes noticeably smooth and regular.

SECTION No. 8.—REFINED WATER-GAS TAR PREPARATION, SURFACE TREATMENT.

This section presents a very un-uniform appearance over most of the area. The aggregate now shows and the surface is ready for a seal coat. This treatment was postponed during the past season only at the expense of considerable repair. In a few places there is a heavy mat that appears to have been pushed up by traffic, but elsewhere the mat is generally worn off.

SECTION No. 9.—ASPHALTIC PETROLEUM, SURFACE TREATMENT.

During the past season, sections 9 and 10 were re-treated uniformly. At the time of inspection they much resembled each other, but 9 is in better general condition. There are only three or four breaks through the mat and, though wavy and uneven, the surface is nearly intact. The marked difference between the east and west halves of the section is not nearly so great as in No. 10. Table 63 gives an analysis of the bituminous material used, and the cost of this re-treatment is given in Table 64.

TABLE 63.—*Analysis of asphaltic petroleum used on sections 9 and 10.*

Specific gravity, 25°/25° C	0. 963
Flash point, °C	31
Burning point, °C	84
Viscosity at 25° C., 50 c.c., Engler specific	128. 4
Loss, 5 hours, at 163° C., 20 grams, per cent	23. 14
Float test on residue, 32° C. (time)	2′ 37″
Float test on residue, 50° C. (time)	1′ 4″
Percentage of total bitumen insoluble in 86° B. naphtha	5. 96
Fixed carbon, per cent	4. 62
Soluble in CS_2 (total bitumen), per cent	99. 94
Organic matter insoluble in CS_2, per cent	0. 04
Inorganic matter insoluble in CS_2, per cent	0. 02
Total	100. 00

SECTION No. 10.—RESIDUAL PETROLEUM, SURFACE TREATMENT.

This experiment continues to be the most troublesome section of the entire project. Reference to previous reports will disclose that it has had repeated attention, being once scarified and rebuilt and once re-treated. In the spring of 1915, after having been very muddy during the preceding winter, it had an irregular wavy mat and there were numerous spots where the aggregate was exposed. It rapidly disintegrated at these points and considerable repair work became necessary. Finally, on August 16 to 18, 1915, a second re-treatment, using asphaltic petroleum, was given. This re-treatment was extended over experiment No. 9 and its details are given in the description of that section. At the time of inspection the west half of the section against the track was in fair condition, but the half along the gutter was muddy and showed a tendency to disintegrate. A line of potholes existed along the middle. Much patching will be required as soon as weather permits. In a few places the road metal is raveling and the winter calks on the horses' shoes have cut entirely through the mat on the east side of the road. It appears from a few breaks just forming at the time of inspection that it is this cutting of the mat which starts the numerous potholes. The cost of this re-treatment is shown in Table 64.

TABLE 64.—*Materials and cost data for surface re-treatments.*

Section No.	Bituminous material.	Area of section (square yards).	Quantity of material per square yard.			Cost per square yard (cents).							
			Bituminous material (gallons).	Gravel (cubic yards).	Sand (cubic yards).	Bituminous material.	Gravel.	Sand.	Cleaning surface.	Applying bituminous material.	Applying sand or gravel.	Supervision.	Total.
9	Asphaltic petroleum, cold application	761	0.197	(1)	0.016	2.6	(1)	3.6	0.1	0.4	0.4	0.4	7.5
10	.....do	1,013	.172	(1)	.016	2.4	(1)	3.6	.2	.6	.5	.5	7.8

[1] Not ascertained.

MAINTENANCE DURING 1915.

In addition to the general re-treatments above described, the patrol system of maintenance was continued during the year. Table 65 presents the total cost of this maintenance and the re-treatments, together with the total cost of each experiment to December 31, 1915.

TABLE 65.—*Costs of construction and of surface mainteannce to December 31, 1915, of 1911 experiments at Chevy Chase, Md.*

Experiment No.	Date completed.	Area.	Maintenance cost of experiment.				Construction per square yard (cents).		
			To 1913.	1914 [1]	1915	Total.	Construction.	Maintenance.	Total.
	1911.	*Sq. yds.*							
1	Oct. 31	1,581	$0.00	$91.48	$36.97	$128.45	46.18	8.12	54.30
2	...do.....	705	.00	.00	16.14	16.14	64.42	2.29	66.71
3	Nov. 18	1,555	.00	.00	14.71	14.71	64.69	.95	65.64
4	Nov. 8	1,555	4.05	2.54	40.18	46.77	57.18	3.00	60.18
5	Dec. 2	1,447	262.57	.90	42.03	305.50	58.27	21.11	79.38
6	Nov. 23	1,555	3.47	.00	32.15	35.62	68.22	2.29	70.51
7A	Dec. 5	131	1.43	.45	4.70	6.58	59.96	5.02	64.98
7B	...do.....	848	67.88	1.33	24.50	93.71	54.80	11.05	65.85
	1912.								
8	Aug. 24	1,477	80.64	.00	50.16	130.80	[2] 39.59	8.86	48.45
9	June 4	761	39.65	44.86	63.71	148.22	42.01	19.48	61.49
10	Nov. 22	1,013	19.05	286.62	132.17	437.84	44.31	43.22	87.53
11	Dec. 16	377	.00	.00	.00	.00	81.51	.00	81.51

[1] Differences between these quantities and those appearing in Table 25, page 34, U. S. Dept. Agr. Bulletin 257, are due to a distribution of "General expenses," not made in the earlier table.

[2] The construction costs here shown for sections 8, 9, and 10 are uniformly 32.58 cents higher than those appearing in the original table of costs on page 9 of Circular No. 99. The amount represents the cost of the 2-inch top course of water-bound macadam, and it is added here in order to make the costs of the wearing courses of these sections comparable with the costs of penetration and mixed surfaces on other sections.

A traffic census is taken every 13 days for a 16-hour period. A tabulation of the maximum and average of each class of traffic for the period between March 8, 1915, and February 22, 1916, is the same as that taken for the 1912 Chevy Chase experiments. Each side of the road carried traffic in one direction only.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT JAMAICA, N. Y., 1911.

OIL-CEMENT CONCRETE, OIL-ASPHALT, TAR, AND FLUXED NATIVE ASPHALT.

The original report of these experiments was published in Circular No. 98, and reports of annual inspections and repairs are given in Circular No. 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletins Nos. 105 and 257. The following report relates to the condition of the pavement on January 22, 1916.

Experiment No. 1.—Oil-Cement Concrete.

The bituminous surface treatment is worn away to a very considerable extent. At present the concrete is exposed in many large and small patches, and is generally somewhat worn and potted, especially at the street intersection.

Experiment No. 2.—Cut-back Oil-Asphalt, Mixing Method.

This experiment will not be reported on again, excepting for the easterly 50 feet. It was entirely scarified in October, 1915, with the exception of the easterly 50 feet, shaped and rolled, and then surfaced with 2 inches of asphaltic concrete prepared according to the Topeka specification. The easterly 50 feet is still in fair condition in the center, but is somewhat wavy along the sides.

Experiment No. 3.—Fluxed Native Asphalt, Mixing Method.

This section is in practically the same condition as indicated in the last inspection report. The waves along the north side for the easterly 30 feet have become somewhat deeper and there is a slight waviness appearing along both sides throughout the entire length of the section.

Experiment No. 4.—Refined Coal Tar, Mixing Method.

This section is in good condition for a width of about 15 feet along the center. It has become somewhat wavy along both sides throughout its entire length. On the south side from station 10+68 to the east end of the section for a width of about 5 feet, where the seal coat was worn off last year, the pavement is now crumbling.

EXPERIMENT No. 5.—CUT-BACK OIL ASPHALT, MIXING METHOD.

From the west end up to station 12+50, with the exception of that part opposite Hardenbrook Street, this section is badly worn out and should be rebuilt. The part opposite Hardenbrook Street is still in fair condition. From station 12+50 to the east end of the section the pavement is fairly good, but the south half of it shows considerable wear and the indications are that this part will need to be rebuilt within a year. No work has been done on this section, except that about six holes were repaired by the borough maintenance crew during the past summer.

EXPERIMENT No. 6.—OIL-ASPHALT, PENETRATION METHOD.

This section is practically in the same condition as indicated in the last inspection report, except that the seal coat has worn until it has entirely disappeared in some places. A slight waviness is developing along both sides over the entire length of the section. The narrow strip where the seal coat had been picked up last year has healed and is not visible now.

EXPERIMENT No. 7.—REFINED COAL TAR, PENETRATION METHOD.

This section is still in good condition, with the exception of a strip about 5 feet wide along the south side, where it is disintegrating throughout its entire length.

EXPERIMENT No. 8.—FLUXED NATIVE ASPHALT, PENETRATION METHOD.

This section is apparently in the same condition as indicated in the last inspection report, except for a small hole 1 foot long and 2 feet wide on the south edge at station 17+60.

EXPERIMENT No. 9.—OIL ASPHALT, PENETRATION METHOD.

This section appears to be in about the same condition as indicated in the last inspection report, except that the narrow strip where the seal coat was picked up has healed and is not now visible.

In reference to this experimental road and the waviness which has been developing along the sides of all of the bituminous sections, it seems well to call attention to the fact that this road was originally built about 1895 as a plain macadam road 18 feet wide, and about 1905 it was reconstructed and surfaced for a width of 25 feet by widening 3½ feet on each side of the old road. It seems probable that the newer part has not the depth of stone or was not as thoroughly compacted as the 18 feet in the center.

SUPPLEMENTARY REPORT OF EXPERIMENT MADE AT AMES, IOWA, 1910.

OIL-ASPHALT GRAVEL.

The original report of this experiment was published in Circular No. 90, and reports of succeeding annual inspections appear, respectively, in Circulars Nos. 98 and 99 of the Office of Public Roads and in U. S. Department of Agriculture Bulletins Nos. 105 and 257.

The driveway on which this experiment was made is 27 feet wide between gutters, but owing to local conditions traffic is confined practically to the eastern two-thirds of the pavement. Several slight inequalities appeared in the traveled way in 1914, and these were partly eliminated by reshaping the road with a grader. The surface was then treated with a light asphaltic oil, but the effect of this treatment had almost entirely disappeared in December, 1914.

In June, 1915, a similar treatment of very light oil was applied, with no more permanent effect than that of the previous one.

In October, 1915, a heavier asphaltic oil was applied to the traveled portion of the road at the rate of one-half gallon per square yard. This work was done under the direction of the superintendent of the grounds and represents the manitenance the roadway has received since its construction in 1910. When inspected December 10, 1915, the gravel surface was well crowned and was covered with a cushion about three-fourths of an inch thick, slightly wavy, but dense and well compacted.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT KNOXVILLE, TENN.

TAR AND OIL PREPARATIONS.

The original report of these experiments was published in Circular No. 94, and reports of subsequent annual inspections appear in Circulars Nos. 98 and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletins Nos. 105 and 257. The last inspection was made December 10, 1915.

These experiments consisted of three bituminous macadam sections constructed by the penetration method. The binders used were, for section No. 1 a refined coal tar, section No. 2 a refined tar preparation, and section No. 3 an oil-asphalt. By January, 1913, section No. 1 had raveled throughout its entire area and by November, 1914, had failed completely except for two small areas. Section No. 2 showed only a small number of raveled places in January, 1913, but by November, 1914, had become so seriously pitted that reconstruction seemed necessary. Both sections impeded motor traffic noticeably. Section No. 3, on the other hand, was still in excellent condition.

In the spring of 1915 the county road officials ordered the holes in sections Nos. 1 and 2 filled with crushed stone. After this rock had been compacted by traffic, a surface treatment of light asphaltic oil was applied to the three sections. Section No. 3 is readily recognized by its smooth, even surface and well-preserved cross section.

As these experiments are no longer comparable as types of bituminous macadam pavement, their behavior will not be reported hereafter.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT YOUNGSTOWN, OHIO, 1910.

SLAG, SLAG AND LIME, SLAG AND WASTE SULPHITE LIQUOR PREPARATION, AND SLAG AND TAR.

The original report of these experiments was published in Circular No. 92 and subsequent reports of anuual inspections are given in Circulars Nos. 94, 98, and 99, Office of Public Roads, and in U. S. Department of Agriculture Bulletins Nos. 105 and 257. The following is a report of the condition of the roadway on December 3, 1915. The sections are discussed in the order of their section numbers, beginning at Mahoning Avenue. With the exception of the tar-slag section, the road was covered with a thin sheet of snow at the time of the inspection, which concealed some of the surface details.

Section No. 1.—Blast-Furnace Slag.

The condition of this section has not changed appreciably during the past year. The surface is somewhat worn and pulverized in the middle of the road and wide, shallow ruts are noticeable in the wheel tracks. These ruts are not so pronounced as in the next two sections, however. Aside from these defects, the surface is smooth, uniformly worn, and free from large protruding stones.

Section No. 2.—Blast-Furnace Slag and Lime.

The general condition of this section is about the same as that of section No. 1. The ruts are somewhat more pronounced, particularly the one on the west side of the traveled way, and a depression, which was evidently due to wear, was noted about 50 feet from the north end of the section.

Section No. 3.—Blast-Furnace Slag and Waste Sulphite Liquor Preparation.

Little change has taken place in the condition of this section during the past year. About 100 feet from the north end two shallow depressions have formed in the wheel tracks, and for 200 feet from the north end the surface is worn and slightly depressed in the middle of the road. The ruts referred to in the two preceding sections extend to the top of the slight grade near the middle of this section. The south half of the section, which lies on the grade, is noticeably better than the north half and is one of the best preserved parts of the entire road.

SECTION NO. 4.—BLAST-FURNACE SLAG AND REFINED COKE-OVEN TAR.

The greater portion of this section was constructed over a deep fill and, as noted in previous inspection reports, initial failure was due to unequal settlement. The surface over the fill and the short stretch to the north has disintegrated and numerous holes and depressions have formed, ranging from a square foot to a square yard in area. The south 50 feet of the section, which has not suffered from settlement, remains practically intact and presents a smooth, true surface. The wearing surface was cut through with great difficulty and it was necessary to use a sharp pick in order to remove a small section for examination.

SECTION NO. 5.—BLAST-FURNACE SLAG.

As noted in former inspection reports, this section is lower at its junction with section No. 4 by about 1½ inches. The ruts in the portion lying in the damp cut remain. The south one-third of the section, which at the last inspection was in very satisfactory condition, has developed two depressions at 165 feet and 135 feet, respectively, from the south end. Both were about 2⅓ inches in depth and showed signs of raveling.

SECTION NO. 6.—BLAST-FURNACE SLAG.

This section has not changed materially during the past year. The ruts are wide and more pronounced than in the preceding sections, but there is less loose pulverized material in the middle of the road. There are two rather deep depressions in the traveled way near the middle of the section and three long, deep ones in the east rut in the north 100 feet of the section. However, there was no evidence of raveling in any of these depressions.

SECTION NO. 7.—BLAST-FURNACE AND OPEN-HEARTH SLAG.

The condition of this section has not changed appreciably in the past 12 months. The surface as a whole is firm and well bound and noticeably harder than any of the other sections, except that portion of No. 4 which still remains intact.

Several years ago the fill near the south end of the section settled irregularly and a deep hole was formed. This has not been repaired and continues to be a menace to traffic.

SUPPLEMENTARY REPORT OF EXPERIMENTS AT GARDEN CITY, BUCKLIN, FORD, AND DODGE CITY, KANS., 1908.

SAND-CLAY.

The original report of these experiments is contained in circular No. 90, and reports of subsequent annual inspections are published in Circulars Nos. 92, 94, 98, and 99, Office of Public Roads, and in

U. S. Department of Agriculture bulletins Nos. 105 and 257. The reports for the year 1915 are subjoined.

These roads are maintained by the highway officials of the respective counties in which they are located. They are subject to heavy seasonal traffic, due to the marketing of cereal crops. The usual load is about 80 bushels of wheat or shelled corn hauled in narrow-tired wagons. Loads of 100 bushels are not infrequent.

EXPERIMENT AT GARDEN CITY, KANS.

This road was inspected December 20, 1915. There had been no rainfall in more than 2 months, during which time the roadway was subjected to much heavy horse-drawn traffic, due to the marketing of wheat and corn. This had developed depressions from 2 feet to 4 feet square in the middle half of the road surface at intervals of from 150 feet to 300 feet. The depressions were from 2 inches to 4 inches deep. Where free from holes, the road is well crowned.

The road has been maintained by filling depressions with gypsum clay and by dragging with a 3-bladed steel drag after each rain. The dragging had been done approximately twice a month up to the time of the protracted drought above mentioned. As a consequence the ditches are open, the shoulders are well shaped, the edges of the sand-clay surface are protected from erosion, and the entire roadway has a neat and well-kept appearance.

EXPERIMENT AT BUCKLIN, KANS.

This road was inspected December 20, 1915, and its condition found to be as follows:

Beginning at the southern end of the section for the first one-third of a mile the cross section was flat and two wide, shallow ruts had formed. There were no places where the sand-clay mixture had broken through, but several gave evidence of weakening under the heavy hauling due to marketing the cereal crops.

In the next one-third of a mile the road is in poor condition. Deep ruts have developed throughout this entire distance and in several places have worked through the sand-clay surface. The cross section is flat and ridges which obstruct lateral drainage have formed along the outside edge of the sand-clay surface. The condition of this section is so unsatisfactory that traffic avoids it by going outside the ditch lines.

The remainder of the road, approximately one-third mile, is in fair condition. It has sufficient crown to shed water, the ditches are open, and only a few depressions have formed. The holes in the approach to the south end of the bridge over the Arkansas River, which were reported in November, 1914, had been filled with new material.

The unsatisfactory condition of the road is ascribed to lack of care of the road during and after the very heavy rains of the past summer. The roadway can be saved by the addition of suitable new material and by reshaping the surface.

EXPERIMENT AT FORD, KANS.

This road was inspected December 20, 1915. In the first 100 feet south of the bridge over the Arkansas River the road has become flat. One depression has formed at the end of the bridge and at two other places on the filled approach to the bridge the sand-clay surface has been cut through.

The remainder of the section has been shaped with a road grader, but too much sand was brought upon the surface from the ditches during this process. In consequence the surface has become weakened and two deep ruts have formed under traffic.

The depressions should be filled and a thin dressing of new material applied to the entire surface to take up the excess of sand.

SUPPLEMENTARY REPORT OF EXPERIMENTS MADE AT BOWLING GREEN, KY., 1907.

KENTUCKY ROCK ASPHALT.

The original report of this experiment was published in Circular No. 89, and reports of annual inspections are given in Circulars Nos. 90, 92, 94, 98, and 99, and in U. S. Department of Agriculture Bulletins Nos. 105 and 257. The inspection on which this report is based was made December 13, 1915.

This work has not been repaired or cared for in any respect since its construction. Débris carried or dropped upon it has been swept by rain and traffic into ridges on each side, which interrupt lateral drainage and hold dirt on the surface. Consequently the deterioration has not resulted from traffic only. The failure is most marked in the western one-third, where the surface is full of holes varying from 4 square feet to 12 square feet in area. In the middle one-third of the pavement length there is one large broken area at the south edge which is 4 feet wide by 10 feet long. The eastern one-third of the section is still practically intact. Here the most noticeable defect is a shallow unbroken rut on the south side made by a heavy concentrated load during construction and not entirely eliminated by subsequent rolling. Where the surface is broken the asphalt has disappeared and the rocks are loose. Where the binder has not failed the surface is smooth and hard and firm.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 408

**Joint Contribution from the Bureau of Entomology,
L. O. HOWARD, Chief, and the Bureau of Chemistry,
CARL L. ALSBERG, Chief.**

Washington, D. C. ▼ **October 28, 1916**

EXPERIMENTS DURING 1915 IN THE DESTRUCTION OF FLY LARVÆ IN HORSE MANURE.[1]

By F. C. COOK, *Physiological Chemist, Bureau of Chemistry*, and R. H. HUTCHISON, *Scientific Assistant, Bureau of Entomology.*

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INTRODUCTION.

This bulletin is a report of experiments on the chemical treatment of manure during 1915, conducted with a view to destroying the fly larvæ therein without injuring the manure for agricultural purposes. As in the experiments previously reported, the cooperative arrangement between the Bureaus of Entomology and Chemistry was continued.

The experiments carried out during 1913 and 1914 have been fully reported in Department Bulletins 118 (1)[2] and 245 (2) and include tests of the larvicidal action of a large number of inorganic and organic compounds. Material from several plant sources was included among the organic compounds tested. The results of the experiments during 1913 and 1914 pointed to a number of substances having pronounced larvicidal value, but the majority of these substances did not meet the full requirements, viz, (1) cheapness; (2) noninjurious action on the bacterial flora, on the chemical composition of the manure, and on the growth of plants;[3] (3) lack of extremely toxic properties.

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[1] Experimental work during the summer was conducted on the farm of the Bureau of Animal Industry at Bethesda, Md., and during the autumn at the Louisiana Experiment Station at Baton Rouge, La. The entomological work at Baton Rouge was done by Mr. J. L. Webb, of the Bureau of Entomology; the bacteriological counts at Washington were made by Dr. L. P. Shippen of the Bureau of Chemistry, and at Baton Rouge by Dr. C. W. Edgerton and Dr. Harry Morris of the State Experiment Station. Thanks are due Dr. W. R. Dodson, Director of the Louisiana State Experiment Station, for facilitating the work at Baton Rouge.

[2] Numbers in parenthesis refer to "Literature cited," p. 19.

[3] A detailed discussion of the effect of boron on plants and plant growth is embodied in an article in the Journal of Agricultural Research, vol. 5, No. 19, page 877, "Boron: Its absorption and distribution in plants and its effect on growth," by F. C. Cook.

Of all the substances which were found to be effective, borax was the cheapest, most generally available, and the most easily transported and handled, but it was open to the objection that excessive amounts added to manure (the probable result of carelessness in application) would result in injury to plants grown in soil to which this manure would be applied (3). It was accordingly considered advisable in these experiments to restrict the use of borax to garbage heaps, outhouses, offal of various kinds, in fact, to any possible breeding material not intended for use as a fertilizer, and to recommend powdered hellebore for the treatment of all material likely to be used for fertilizing purposes.

Powdered hellebore, when used at the rate of one-half pound per 8 bushels of manure, showed a larvicidal action about equal to that of borax when the latter was applied at the rate of two-thirds of a pound per 8 bushels, and it was evident that no injurious action either on manure or on the growth of plants followed the application; in fact, the hellebore was found to have disappeared from manure after a period of 30 days. The price of powdered hellebore, with that of drugs in general, has increased considerably during the past 2 years.

The fact that a plant material was found possessing such high larvicidal powers led to an investigation during the past season of various plant materials which were known to contain alkaloids or glucosids, or were thought to possess some value as larvicides. Included in the list to be studied were a number of common weeds, parts of trees, shrubs, etc., which at the present time have no economic value. There seemed to be a possibility that this line of experiments might point to some widely distributed and abundant plant containing a substance specifically poisonous to coprophagous larvæ.

The season's work also included tests with fertilizer mixtures, such as calcium cyanamid and acid phosphate, calcium cyanamid and kainit, etc., with the idea that some combination might be found which would possess a high larvicidal power and also increase the fertilizing value of the manure.

METHODS.

The methods employed were the same in most details as those described in Department Bulletins 118 (1) and 245 (2). The same cages that had been employed during the season of 1914 were found to be satisfactory. As in the previous tests, 8 bushels of fresh larvæ-infested manure were added to each cage and treated in three layers. When any substance was used dry it was also applied in three layers, and each layer of the treated manure was sprinkled with water. The methods for the open-pile experiments were slightly modified, so that instead of collecting and counting the puparia after a period of 6 to 8 days following the treatment, a pyramidal cage having a flytrap at the top was placed over the pile immediately after the last treatment, and all emerging flies collected in the trap were chloroformed and counted. The figures given in the tables are for the house fly only. *Stomoxys calcitrans*, certain species of Phorbia, and various Sarcophagidæ were often present, but in comparatively small numbers. In addition to the cage and open-pile experiments a few tests were made, placing manure in large wooden boxes which were lined with heavy paper to prevent the migration of larvæ through the cracks or corners. Netting and flytraps were attached to the tops of the boxes. Methods of chemical and bacteriological examination of the manure were practically the same as those employed in previous investigations, and described in detail in Department Bulletin 118 (1), pages 3 to 8, with the exception that nitrates were determined colorimetrically by means of diphenylamin. The examinations were made only in the case of a few substances where favorable larvicidal action was shown. The nitrogen results[1] obtained by the distillation method with magnesium oxid (A. O. A. C. method) (7), are included in the tables under the head of amid nitrogen, the ammonia nitrogen as determined by the Folin and Macallum aeration method (4) being deducted from the nitrogen results by the distillation method.

GENERAL ACCOUNT OF SUBSTANCES USED.

Most of the substances tested during the past season fall naturally into two groups: (1) Infusions of poisonous plant materials, and (2) fertilizing mixtures.

PLANT INFUSIONS.

Plant infusions were prepared by mixing a weighed amount of powdered or finely divided material with a measured quantity of water, stirring well, and allowing the mixture to stand overnight. The resulting infusion was used within 24 hours, applying it to the manure with a sprinkling can from which the nozzle was removed if there was any tendency to clog. In this way, the solid as well as the liquid portions of the plant material were directly applied to the manure. The results of cage experiments with plant materials are shown in Table 1, and the results of the open-pile experiments in Table 2.

---

[1] All nitrogen determinations were made by the Nitrogen Laboratory of the Bureau of Chemistry.

TABLE 1.—*Destruction of fly larvæ in horse manure—Results with poisonous plant materials.*

[Cage experiments, Bethesda, Md., 1915.]

No.	Material used.	Form used.	Treatment of 8 bushels of manure, using 10 gallons of infusion (amount of plant material used per 10 gallons).	Flies emerged (number).	Apparent larvicidal effect (per cent of control average).	Flies emerged from control cages.	
						Number.	Average.
1	Asclepias (*Asclepias tuberosa*).	Powdered root	A, 1 pound	338	54	385	733
			B, 1 pound	431	42	1,345	
2	Berberis (*Berberis aquifolium*).	do	A, 1 pound	207	60	982	508
			B, 1 pound	40	92	35	
3	Bitter-sweet (*Solanum dulcamara*).	Powdered entire plant.	A, 1 pound	378	26	982	508
			B, 1 pound	92	82	35	
4	Black hellebore (*Helleborus niger*).	Powdered root	A, ½ pound	0	100	385	733
			B, ½ pound	583	21	1,345	
5	Black locust (*Robinia pseudacacia*).	Powdered bark	A, 1 pound	827	50	1,164	1,639
			B, ½ pound	1,009	39	2,114	
6	Castor bean (*Ricinus communis*).	Ground cake	A, 4 pounds	2,317	0	1,141	1,488
			B, 2 pounds	2,433	0	2,161	
			C, 1 pound	2,726	0	1,164	
			D, 1 pound	587	0	982	508
			E, 1 pound	198	62	35	
7	Cinchona (*Cinchona succirubra*).	Powdered bark	A, 1 pound	23	97	385	733
			B, 1 pound	187	75	1,345	
8	Hellebore (*Veratrum viride*).	Powdered root	A, ½ pound[1]	116	92	1,075	1,474
			B, ½ pound[1]	53	97	1,872	
9	Hemlock, poison (*Conium maculatum*).	Powdered fruit	A, 1 pound	976	41	1,164	1,639
			B, ½ pound	1,828	0	....	
			C, ¼ pound	1,492	9	2,114	
10	Jaborandi (*Pilocarpus jaborandi*).	Powdered leaves	A, 1 pound	305	59	385	733
			B, 1 pound	604	18	1,345	
11	Jamaica dogwood (*Piscidia erythrina*).	Powdered bark of roots.	A, 4 pounds	1,045	30	....	1,474
			B, 2 pounds	797	46	1,075	
			C, 2 pounds	672	55	1,872	
			A, 1.35 pounds	573	65	1,164	1,639
			B, 0.67 pound	716	57	2,114	
12	Larkspur (*Delphinium* sp.).	Ground seeds	A, 1 pound	284	81	1,075	1,474
			B, 1 pound	418	72	1,872	
13	Laurel (*Kalmia latifolia*).	Dried leaves	A, 1 pound	3,553	0	1,164	1,639
			B, ½ pound	2,423	0	2,114	
			C, ¼ pound	1,583	0		
14	Quassia (*Picrasma excelsa*).	Powdered chips	A, 4 pounds	44	97	1,141	1,488
			B, 2 pounds	2,501	0	2,161	
			C, 1 pound	727	52	1,164	
15	Soapweed (*Agave lecheguilla*).	Macerated roots	A, 2½ pounds	2,282	0	1,141	1,488
			B, 1¾ pounds	1,308	12	2,161	
			C, ¾ pound	1,123	25	1,114	

[1] Applied dry, 10 gallons water added.

TABLE 2.—*Destruction of fly larvæ in horse manure—Results with poisonous plant materials.*

[Open-pile experiments, Bethesda, Md., 1915.]

No.	Material used.	Form used.	Treatment of 4 bushels manure, using 5 gallons infusion (amount of plant material used per 5 gallons).	Flies emerged (number).	Apparent larvicidal effect (per cent of control average).	Flies emerged from control cages.	
						Number.	Average.
1	Absinthe (*Artemisia absinthium*).	Powdered leaves	A, ½ pound	450	0	391	342
			B, ½ pound	683	0	293	
2	Anthemis (*Anthemis nobilis*).	Powdered flowering heads.	A, ½ pound	331	3.0	391	342
			B, ½ pound	653	0	293	
3	Hellebore (*Veratrum viride*).	Powdered roots	A, ¼ pound	353	93.0	7,192	4,791
			B, ¼ pound	636	87.0	2,391	
			C, ¼ pound[1]	241	51.0	528	492
			D, ¼ pound[1]	96	80.5	456	
4	Poke root (*Phytolacca decandra*).	do	A, ½ pound	1,873	0	528	492
			B, ½ pound	710	0	456	

[1] Applied dry, 5 gallons water added.

The results obtained during 1914 with corn cockle (*Agrostemma githago*), a commercial extract of tobacco (*Nicotiana tabacum*) containing 40 per cent nicotine sulphate, and stramonium (*Datura stramonium*) showed no marked or consistent larvicidal action, and these substances were not tested during the past season.

A few experiments with hellebore (*Veratrum viride*, *Veratrum album*) were carried out this year to supplement the results of the previous season. The figures obtained both in the cage and open-pile experiments confirm the statements previously made as to its effectiveness. The results in Table 2 indicate that the hellebore infusion which had been standing for 20 to 24 hours was more effective than the hellebore applied as a powder and immediately sprinkled with water.

Two tests were made during the past season, using a 1 per cent infusion of ground larkspur seeds (*Delphinium* sp.). An apparent larvicidal action of 72 and 81 per cent was obtained. In view of the cost and the comparatively low efficiency of this material it is hardly to be considered a practical larvicide.

An infusion prepared from the macerated roots of soapweed (*Agave lecheguilla*) was again tested, but the results were practically negative.

During 1915, 18 plant substances were tested, and a study of Tables 1 and 2 shows that Berberis, Cinchona, and quassia were the only substances which gave indications of having any effect on fly larvæ. Berberis and Cinchona are both expensive, and as apparently large amounts of quassia are necessary to act as an effective larvicide none of these three substances can be considered practicable. Black hellebore (*Helleborus niger*) was used in two experiments, but the results were inconsistent. This plant is not only of a different genus but belongs to a different family of plants than *Veratrum viride* and *Veratrum album.*

FERTILIZING MIXTURES.

During the season of 1913 several tests were made with calcium cyanamid, kainit, and acid phosphate, using each separately. The results were such that no one of these substances could be considered a good larvicide when used in reasonable amounts. As calcium cyanamid and kainit showed some larvicidal action, and as the value of using a fertilizer as a larvicide is obvious, experiments were started during 1915 with the hope of finding an effective fertilizer mixture. In addition to the foregoing, gypsum, Chile saltpeter, and muriate of potash were tried in mixtures. The results of these tests are summarized in Tables 3, 4, 5, and 6.

CHILE SALTPETER ($NaNO_3$) and ACID PHOSPHATE $CaH_4(PO_4)_2$, $Ca_2H_2(PO_4)_2$, $Ca_3(PO_4)_2$.

A mixture of 2 pounds each of Chile saltpeter and acid phosphate was used in duplicate cage experiments (Table 3, No. 3). The results were poor, showing on the average about a 36 per cent larvicidal action.

TABLE 3.—*Destruction of fly larvæ in horse manure—Results with fertilizer mixtures.*

[Cage experiments, Bethesda, Md., 1915.]

No.	Material used.	Treatment of 8 bushels manure with following amounts of mixtures, then sprinkled with 10 gallons of water.	Flies emerged (number).	Apparent larvicidal effect (per cent of control average).	Flies emerged from control cages.	
					Number.	Average.
1	Calcium cyanamid+ acid phosphate.	A, 1 pound calcium cyanamid+4 pounds acid phosphate.	156	90.5	....	....
		B, 2 pounds calcium cyanamid+ 2 pounds acid phosphate.	16	99.0	1,075	1,474
		C, 1¼ pounds calcium cyanamid+ 2½ pounds acid phosphate.	89	94.0	1,872	
2	.....do...............	A, ¾ pound calcium cyanamid+ 6 pounds acid phosphate.	905	67.5	2,910	2,787
		B, ¾ pound calcium cyanamid+ 6 pounds acid phosphate.	831	70.2	2,665	
3	Chile saltpeter+ acid phosphate.	A, 2 pounds saltpeter+2 pounds acid phosphate.	1.934	30.6	2,910	2,787
		B, 2 pounds saltpeter+ 2 pounds acid phosphate.	1,661	42.5	2,665	
4	Calcium cyanamid+ gypsum.	A, 1 pound calcium cyanamid+ 2 pounds gypsum.	610	78.2	2,910	2,787
		B, 1 pound calcium cyanamid+2 pounds gypsum.	385	86.3	2,665	
5	Borax + gypsum....	A, ¾ pound borax+0.3 pound gypsum..	37	98.7	2,910	2,787
		B, ¾ pound borax+0.3 pound gypsum..	22	99.0	2,665	

CALCIUM CYANAMID ($CaCN_2$) and GYPSUM ($CaSO_4$).

A mixture of 1 pound of calcium cyanamid and 2 pounds of gypsum was used in duplicate in cage experiments at Bethesda, Md., with an average larvicidal action of 82 per cent (Table 3, No. 4). This is very nearly as high as the average larvicidal action for mixtures of 1 pound of calcium cyanamid with varying amounts of acid phosphate, and indicates that gypsum may be used in place of acid phosphate in mixtures with calcium cyanamid.

BORAX ($Na_2B_4O_7$) and GYPSUM ($CaSO_4$).

Although borax is not a fertilizer, it was tried in a mixture with gypsum with the idea that the SO_4 radical in gypsum might tend to reduce the toxic action on plant growth, which is known to result from the application of large amounts of borax. The figures given in Table 3, No. 5, show that borax gave excellent larvicidal results in the presence of gypsum, but the effect of manure treated with this mixture on plant growth was not determined.

CALCIUM CYANAMID, KAINIT (KCl and $MgSO_4$), and ACID PHOSPHATE.

This is an ideal mixture from the point of view of a fertilizer, as it furnishes the three essential elements of plant food, namely, nitrogen, potash, and phosphoric acid.

The results of 8 open-pile experiments, using from one-eighth pound to 1 pound of calcium cyanamid in the mixtures, are recorded in Table 4, Nos. 2 and 3. The larvicidal results were all low and irregular, varying from 10 to 81 per cent.

TABLE 4.—*Destruction of fly larvæ in horse manure—Results with fertilizer mixtures and solutions of calcium cyanamid.*

[Open-pile experiments, Bethesda, Md., and Baton Rouge, La., 1915.]

No.	Material used.	Treatment of 4 bushels of manure with following amounts of mixtures, then sprinkled with 5 gallons of water.	Flies emerged (number).	Apparent larvicidal effect (per cent of control average).	Flies emerged from control cages.	
					Number.	Average.
1	Calcium cyanamid + kainit.	A, 1 pound calcium cyanamid + 1 pound kainit.	93	81.1	377	490
		B, 1 pound calcium cyanamid + 1 pound kainit.	247	49.6	604	
2	Calcium cyanamid + kainit + acid phosphate.	A, ⅛ pound calcium cyanamid + ¼ pound kainit + ½ pound acid phosphate.	1,790	66	7,250	5,392
		B, ⅛ pound calcium cyanamid + ¼ pound kainit + ½ pound acid phosphate.	1,015	81	3,535	
3	....do.............	A, 1 pound calcium cyanamid + 1 pound kainit + 4 pounds acid phosphate.	111	33	....	....
		B, 1 pound calcium cyanamid + 1 pound kainit + 4 pounds acid phosphate.	153	10	....	....
		C, 1 pound calcium cyanamid + 2 pounds kainit + 3 pounds acid phosphate.	86	48	....	....
		D, 1 pound calcium cyanamid + 2 pounds kainit + 3 pounds acid phosphate.	50	60	....	....
		E, 1 pound calcium cyanamid + 3 pounds kainit + 2 pounds acid phosphate.	48	61	263	163
		F, 1 pound calcium cyanamid + 3 pounds kainit + 2 pounds acid phosphate.	118	32	62	
4	Calcium cyanamid + muriate of potash + acid phosphate.	A, 1 pound calcium cyanamid + 1 pound muriate of potash + 3 pounds acid phosphate.	1,056	0	378	452
		B, 1 pound calcium cyanamid + 1 pound muriate of potash + 3 pounds acid phosphate.	717	0	526	
5	Calcium cyanamid + acid phosphate.	A, ⅓ pound calcium cyanamid + 2⅔ pounds acid phosphate.	176	19	....	....
		B, ⅓ pound calcium cyanamid + 2⅔ pounds acid phosphate.	221	0	....	....
		C, ⅓ pound calcium cyanamid + 2⅔ pounds acid phosphate.	286	0	238	216
		D, ⅓ pound calcium cyanamid + 2⅔ pounds acid phosphate.	186	14	194	
6	.....do.............	A, ½ pound calcium cyanamid + ¾ pound acid phosphate.	850 ca.	30	1,123	1,220
		B, ½ pound calcium cyanamid + ¾ pound acid phosphate.	934 ca.	24	1,317	
7	.....do.............	A, ½ pound calcium cyanamid + 2 pounds acid phosphate.	1,984	63	7,250	5,392
		B, ½ pound calcium cyanamid + 2 pounds acid phosphate.	2,115	60	3,535	
8	.....do.............	A, ½ pound calcium cyanamid + 3 pounds acid phosphate.	789 ca.	35	1,123	1,220
		B, ½ pound calcium cyanamid + 3 pounds acid phosphate.	1,052 ca.	14	1,317	
9	.....do.............	A, ½ pound calcium cyanamid + 3 pounds acid phosphate.	1,426	24	2,576	1,868
		B, ½ pound calcium cyanamid + 3 pounds acid phosphate.	1,233	34	1,160	
10	.....do.............	A, ⅔ pound calcium cyanamid + 1½ pounds acid phosphate.	1,136	13	1,716	1,300
		B, ⅔ pound calcium cyanamid + 1½ pounds acid phosphate.	611	53	884	
11	.....do.............	A, ¾ pound calcium cyanamid + 1½ pounds acid phosphate.	1,127	40	2,576	1,868
		B, ¾ pound calcium cyanamid + 1½ pounds acid phosphate.	922	50	1,160	
12	.....do.............	A, ¾ pound calcium cyanamid + 1½ pounds acid phosphate.	1,297	0	1,716	1,300
		B, ¾ pound calcium cyanamid + 1½ pounds acid phosphate.	1,248	4	884	

TABLE 4.—*Destruction of fly larvæ in horse manure—Results with fertilizer mixtures and solutions of calcium cyanamid*—Continued.

No.	Material used.	Treatment of 4 bushels of manure with following amounts of mixtures, then sprinkled with 5 gallons of water.	Flies emerged (number).	Apparent larvicidal effect (per cent of control average).	Flies emerged from control cages.	
					Number.	Average.
13	Calcium cyanamid + acid phosphate.	A, ¾ pound calcium cyanamid + 4 pounds acid phosphate.	2,377	0	....	....
		B, ¾ pound calcium cyanamid + 4 pounds acid phosphate.	975	38	....	....
14	.....do...............	A, 1 pound calcium cyanamid + 6 pounds acid phosphate.	1,025	35	1,247	1,574
		B, 1 pound calcium cyanamid + 6 pounds acid phosphate.	1,263	20	1,901	
15	.....do...............	A, 1½ pounds calcium cyanamid + 2½ pounds acid phosphate.	62	62	263	163
		B, 1½ pounds calcium cyanamid + 2½ pounds acid phosphate.	61	62	62	
16	Calcium cyanamid in solution.	A, 4 per cent solution of calcium cyanamid, 5 gallons to 4 bushels manure.	598	34	....	....
		B, 4 per cent solution of calcium cyanamid, 5 gallons to 4 bushels manure.	327	64	....	....
		C, 3 per cent solution of calcium cyanamid, 5 gallons to 4 bushels manure.	677	25.2	1,173	904
		D, 3 per cent solution of calcium cyanamid, 5 gallons to 4 bushels manure.	312	65.5	635	
17	.....do...............	A, 4 per cent solution of calcium cyanamid, 2½ gallons to 2 bushels manure.	263	17	552	314
		B, 4 per cent solution of calcium cyanamid, 2½ gallons to 2 bushels manure.	11	96.5	81	

When calcium cyanamid was present in mixtures at the rate of one-half pound per bushel of manure, it is apparent from the results given in Table 6, No. 4, that a satisfactory larvicidal action was obtained. It is evident that practically four times as much cyanamid is required in mixtures for the effective treatment of open piles as for cages or boxes.

CALCIUM CYANAMID, MURIATE OF POTASH (KCl), AND ACID PHOSPHATE.

This mixture, though similar to the one just discussed, showed no apparent larvicidal action in the amounts employed (Table 4, No. 4).

TABLE 5.—*Destruction of fly larvæ in horse manure—Results using calcium cyanamid and acid phosphate mixture.*

[Cage experiments at Bethesda, Md., and box experiments at Baton Rouge, La., 1915.]

No.	Treatment of 8 bushels manure followed by sprinkling with 10 gallons of water.	Flies emerged.	Apparent larvicidal action (per cent of control average).	Number bacteria per gram calculated to dry weight.	Manure, total nitrogen.	Water extract.			
						Alkalinity, cc N/20 NaOH per 100 cc (5 grams manure).	In per cent of total nitrogen.		
							Nitrogen.	Ammonia nitrogen.	Amid nitrogen.
		Number.		*Millions.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
1	A, 1 pound calcium cyanamid +1½ pounds acid phosphate, cages	7	98.7	3,608	0.533	6.25	33.60	2.40	10.73
	B, Do	1	99.0	2,646	.456	5.75	36.84	4.20	11.05
	C, Control	982	....	18,750	.449	7.25	29.84	2.90	9.57
	D, Do	35	....	25,500	.379	8.00	29.53	3.60	11.17
2	A, 1 pound calcium cyanamid +8 pounds acid phosphate, cages	472	83.8	20.5	.519	3.25	25.82	5.97	....
	B, Do	317	88.6	10	.519	3.00	28.71	9.06	....
	C, Control	4,410	....	36	.440	3.75	25.45	1.70	....
	D, Do	2,665	....	50	.582	4.00	21.14	1.72	....
3	A,[1] 1 pound calcium cyanamid+6 pounds acid phosphate, boxes	135	95.9	1,600	.442	1.50	38.01	11.76	13.58
	B, 1⅓ pounds calcium cyanamid+6 pounds acid phosphate, boxes	650	80.0	900	.428	4.00	34.11	11.91	14.26
	C,[1] 2 pounds calcium cyanamid+12 pounds acid phosphate, boxes	307	90.5	800	.449	3.50	24.94	11.80	25.62
	D,[1] Control	3,238	....	1,400	.379	2.75	29.55	7.92	13.19

[1] 3 A, C, and D contained nitrates.

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TABLE 6.—*Destruction of fly larvæ in horse manure—Results using 4 per cent solutions of calcium cyanamid (series 1 and 2), and with dry calcium cyanamid and acid phosphate mixtures (series 3 and 4).*

[Open pile experiments, Baton Rouge, La., 1915.]

No.	Treatment of 8 bushels manure.	Flies emerged.	Apparent larvicidal action (per cent of control average).	Number bacteria per gram manure calculated to dry weight.	Manure, total nitrogen.	Water extract.			
						Alkalinity, cc N/20 NaOH per 100 cc (5 grams manure).	In per cent of total nitrogen.		
							Nitrogen.	Ammonia nitrogen.	Amid nitrogen.
		Number.		*Millions.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
1	A, 10 gallons 4 per cent calcium cyanamid solution	(1)	100	2,222	0.735	7.35	45.03	6.26	24.35
	B, Do	(1)	100	600	.604	6.85	35.26	7.28	18.22
	C, Control	(1)	....	347	.653	7.00	30.93	6.74	12.56
	D, Do	(1)	....	857	.688	7.50	34.30	5.96	8.28
[2]2	A, 10 gallons 4 per cent calcium cyanamid solution	924	90.5	1,458	.428	6.75	36.68	11.68	11.50
	B, Do	1,865	79.9	1,154	.435	2.50	27.59	9.66	6.43
	C, Control	9,589	....	909	.449	2.75	21.16	8.69	6.90
	D, Do	8,969	....	723	.423	3.75	29.31	8.97	4.11
[2]3	A, 3 pounds calcium cyanamid+12 pounds acid phosphate, 10 gallons water added	70	57	5,745	.744	3.75	27.98	8.07	10.73
	B, Do	16	90	2,000	.646	3.50	24.30	7.89	13.78
	C, Control	263	....	4,285	.604	3.00	20.53	5.79	3.48
	D, Do	62	....	4,151	.540	1.75	23.33	7.04	3.33
[2]4	A, 4 pounds calcium cyanamid+4 pounds acid phosphate, 10 gallons water added	19	97	182	.625	3.75	26.88	5.76	22.16
	B, Do	4	99	545	.510	5.50	35.30	6.67	20.78
	C, 5 pounds calcium cyanamid+5 pounds acid phosphate[3]	5	99	255	.646	4.25	34.68	6.81	21.37
	D, Do	15	98	1,000	.510	4.60	46.27	9.02	23.92
	G, 3 pounds calcium cyanamid+6 pounds kainit[3]	4	99	1,220	.681	6.25	36.27	6.90	19.83
	H, Do	13	98	511	.744	6.85	45.29	8.47	17.87
	E, Control[3]	511	....	431	.414	3.10	27.05	7.24	16.43
	F, Do	727	....	511	.470	3.35	27.44	7.02	13.83

[1] Piles examined for larvæ on third day after treatment.
[2] Nitrates were present in all samples of series 2, 3, and 4.
[3] 10 gallons of water added per 8 bushels of manure.

CALCIUM CYANAMID AND KAINIT.

The results given in Table 4, No. 1, where 1 pound of each ingredient was used in duplicate tests, show varying and inconsistent action, 50 and 81 per cent. Open-pile experiments given in Table 6, No. 4, G and H, show that where 3 pounds of cyanamid and 6 pounds of kainit were applied in mixture practically all the larvæ were killed.

Chemical and bacteriological examinations were made of samples of manure taken from the last two mentioned experiments. The bacterial count in one sample was twice as high as in the untreated control samples and the other sample gave the same result as the controls. The percentage of total nitrogen, as well as of the various nitrogenous constituents, in the two treated samples, was markedly higher than in the two controls, and the alkalinity also was increased. These changes were due to the presence of nitrogen and lime in the calcium cyanamid.

CALCIUM CYANAMID AND ACID PHOSPHATE.

Varying amounts of calcium cyanamid and acid phosphate were used in preparing mixtures in order to determine the most effective combination. The results of 5 cage experiments at Bethesda, Md., are recorded (Table 3, Nos. 1 and 2). From three-fourths pound to 2 pounds of cyanamid and from 2 to 6 pounds of acid phosphate were used in the various mixtures tested. The larvicidal results, from 90 to 99 per cent, with mixtures containing 1 pound or more of the cyanamid were very satisfactory. It is evident from the results in the table that three-fourths of a pound of cyanamid is not sufficient. Some additional cage experiments and one series of tests in boxes are recorded in Table 5. In the cage experiments mixtures of 1 pound of cyanamid with 1½ pounds of acid phosphate, and 1 pound of cyanamid with 8 pounds of acid phosphate were tested in duplicate. The results agree with those in Table 3, showing that 1 pound of cyanamid in cage experiments was a fairly effective application.

Bacteriological and chemical analyses of samples of manure from the cages are given in Table 5, Nos. 1 and 2. The bacteria were reduced in both series by the treatment, alkalinity was slightly reduced, and the water-soluble and ammonia nitrogen results showed a tendency to increase. The ammonia results in No. 2, where the 8 pounds of acid phosphate were used, were markedly higher than the controls.

The results of the experiments in boxes are given in Table 5, No. 3. They show an apparent larvicidal action averaging 89 per cent. It is probable that the surface exposure of the manure in the boxes is the important feature in determining the effectiveness of this treatment, although these three experiments do not bring this out as fully as might be expected. Box A had a surface exposure of 5 square feet, box B of 8 square feet, box C of 7 square feet, and box D of 7½ square feet.

The bacteria counts averaged 75 per cent as high as for the control sample, 3D. The alkalinity of the water extracts of the manure showed no definite change in any case. The water-soluble nitrogen was increased in two samples, and reduced in the third; the ammonia nitrogen was decidedly increased in the treated samples, while the amid nitrogen was increased only in sample 3C.

The results of several open-pile experiments are shown in Table 4, Nos. 5 to 15, inclusive. The mixtures employed contained from one-third of a pound to 1½ pounds of calcium cyanamid, and from three-fourths of a pound to 6 pounds of acid phosphate per 4 bushels of manure. The larvicidal results were very irregular, but it is evident that 1 pound of cyanamid is not effective in open piles.

Some results of the effect of larger applications of mixtures of cyanamid and acid phosphate in open-pile experiments at Baton Rouge are recorded in Table 6, Nos. 3 and 4.

In series No. 3 the mixture contained 3 pounds of cyanamid and 12 pounds of acid phosphate per 8 bushels of manure. From the two control piles 263 and 62 flies emerged, but using the average of these two figures, a 57 per cent and a 90 per cent larvicidal action was apparently obtained. Attention is called to the fact that from cage 3A, 70 flies emerged, a count higher than the lower control. On account of the uneven infestation of the manure used in these tests the percentages have little value. The number of bacteria in 3B, where a 90 per cent larvicidal action was obtained, was reduced 50 per cent by the treatment. The total nitrogen of the manure apparently was increased by the treatment, as was the water-soluble and ammonia nitrogen. The greatest increase was in the amid nitrogen. There was apparently a slight increase in the alkalinity of the water extracts. Nitrates were detected in all of these samples.

In No. 4, Table 6, 4 and 5 pounds of cyanamid were mixed with equal amounts of acid phosphate. With both mixtures the larvicidal results were highly satisfactory, 97 and 99 per cent of the larvæ being destroyed. No reduction in the number of bacteria in the treated samples was found. An increased percentage of total and amid nitrogen due to the nitrogen of the cyanamid was obtained in all of the 4 samples, while 3 of the 4 samples showed an increase in the water-soluble nitrogen. Less ammonia nitrogen was found in 3 of the 4 samples than in the controls. The alkalinity slightly increased in all cases. All the samples showed the presence of nitrates by the diphenylamin method, the color reactions being stronger in the treated than in the untreated samples.

Many temperature readings of the manure treated with mixtures of cyanamid and acid phosphate were taken. In practically all instances the results of the readings in the case of the treated samples were the same as in the case of the controls. This is in line with the bacterial counts and indicates that no marked action on the bacterial flora had taken place.

It is probable that the cyanamid is the principal toxic constituent of the various mixtures, and the cyanamid which is soluble in water is undoubtedly more toxic than its polymer dicyandiamid.

Kionka (5) has reported experiments showing that 0.1 gram of pure cyanamid is a fatal dose for dogs, when given subcutaneously, while it takes 0.25 gram of dicyandiamid to produce the fatal result. The fatal doses for dogs when administered internally are, respectively, 0.75 and 2 grams. These experiments indicate that cyanamid is three times as toxic as dicyandiamid.

SUSPENSIONS OF CALCIUM CYANAMID.

As the substances which have been found to be effective larvicides act most effectively when applied in solution or suspension, it was considered advisable to test the effect of 3 and 4 per cent solutions of calcium cyanamid. The results of these experiments are recorded in Table 4, Nos. 16 and 17, and Table 6, Nos. 1 and 2.

The results recorded in Table 4, Nos. 16 and 17, can hardly be compared with the other open-pile experiments for the reason that only 2 bushels of manure instead of 4 were used at each treatment. In No. 16 the application was made twice; that is, there was a total of 4 bushels of manure in the pile instead of 12 as in other experiments. In No. 17 only one application was made to each of the 2-bushel piles. Moreover, only large larvæ, probably 3 days old, were present in the manure at the time of treatment. It is not clear how much these conditions would influence the effectiveness of the solution used, but at any rate the larvicidal results were all low and irregular, except in one experiment, No. 17–B.

In series 2, Table 6, where two treatments were applied to each of 4 bushels of manure, in duplicate, one result was rather low (80 per cent), while one was fairly good (90 per cent). In series 1, Table 6, cages were not placed over these piles to catch emerging flies, but an estimate of the larvicidal effect was made from examination of the piles on the third day after treatment. At that time no larvæ were seen in 1A and only one or two in 1B, while the control piles were seen to be heavily infested. In general, the results with solutions of cyanamid were not uniformly favorable, as far as larvicidal action is concerned, and it would require a considerable number of additional experiments to determine just what strength would be uniformly effective.

The bacteria of series 1 and 2, Table 6, showed an increase in three of the four treated samples. No increase of total nitrogen was found, and but one sample, 2A, showed an increase in alkalinity. The water-soluble nitrogen, ammonia nitrogen, and amid nitrogen in the water extracts of the treated samples of both series showed a tendency to increase. Nitrates were detected in all samples of series 2, but were absent from all samples in series 1. In the former series the manure was older, the piles having stood longer before the samples were taken than with series 1.

COMMERCIAL MIXED FERTILIZERS CONTAINING CALCIUM CYANAMID.

Calcium cyanamid is frequently used to furnish the nitrogen of mixed fertilizers, either in whole or in part. Such fertilizers usually do not contain any calcium cyanamid as such, since the cyanamid has been decomposed into urea, ammonia, etc. The percentage of calcium cyanamid used in commercial mixed fertilizers varies with each brand. The commercial fertilizer which was employed in this test contained 12¼ per cent phosphoric acid, 2¾ per cent ammonia, and 2¼ per cent potash.

One-third of a bushel of manure was treated with 1 pound of the mixed fertilizer in a box covered with netting. The sample was then well moistened. Only 2 flies emerged from the box which was treated with the mixed fertilizer, while 909 flies emerged from the control box. The application of the mixed fertilizer in this experiment was a very heavy one, and as but one experiment was carried out, and that one on a small scale, no conclusion can be drawn. As manufacturers employ varying amounts of cyanamid in their mixtures it is impossible to use commercial mixtures as a larvicide with any assurance of obtaining satisfactory results without first testing the mixture in question and determining the amount necessary to apply to the manure to destroy the maggots.

THE AMOUNTS OF FERTILIZER MIXTURES TO APPLY TO PITS AND PILES OF MANURE TO KILL FLY LARVÆ.

From all of the cage tests and the box experiments (Table 5, No. 3) the indications are that mixtures containing 1 pound of calcium cyanamid and 2 to 4 pounds of acid phosphate will destroy a high percentage of the maggots of the house fly present in 8 bushels of manure, when the manure is placed in such receptacles. In these cases the surface treated was much smaller than in an open pile containing the same amount of manure, and as the surface was practically level the mixture could be applied effectively and forced into the manure by sprinkling with water. It seems likely that the mixtures will act effectively when applied to manure in pits where approximately the same conditions exist as in the box or cage tests; that is, where there is only one surface to be treated. One pound of cyanamid in mixtures was used successfully in a box having a surface exposure of 5 square feet and in cages with a surface of 4 square feet. It is therefore suggested that mixtures containing 1 pound of cyanamid and 2 to 4 pounds of acid phosphate be applied to boxes or pits at the above rate per 4 square feet of surface exposure. The ideal way of storing manure is in a water-tight pit. If this is not available, the manure may be thrown into a large box and then effectively treated with the cyanamid mixture at the above rate.

In the treatment of piles of manure it is evident from the results in Table 6, series 4, that 4 pounds of calcium cyanamid applied in mixtures with either acid phosphate or kainit per 8 bushels of manure acts as an effective larvicide. To be sure of retaining all of the nitrogen and ammonia which ordinarily is lost from a pile of manure, a higher ratio of acid phosphate to calcium cyanamid than was used in these tests should be employed. The chemical analyses of No. 4, Table 6, show no changes from the control samples, but the results of Table 5, No. 2, show the advantage of using a large proportion of acid phosphate.

Kainit may be employed in the mixtures together with the cyanamid and acid phosphate. Thus potash, as well as lime, nitrogen, and phosphoric acid, will be added to the manure. The substitution of kainit for part of the acid phosphate makes no apparent difference in the larvicidal action of the mixture. It is important to apply in the mixture one-half pound of calcium cyanamid per bushel of manure. The manure should be thoroughly sprinkled with water after each application of the cyanamid mixture. It is probable that gypsum may be substituted in whole or in part for the acid phosphate.

THE VALUE OF USING CALCIUM CYANAMID, ACID PHOSPHATE, AND KAINIT ON MANURE.

It is likely that calcium cyanamid, which contains lime in amounts equivalent to 70 parts of $Ca(OH)_2$ per 100, if used alone on fresh manure in any considerable amount, will expel some of the nitrogen and ammonia present in the manure. Acid phosphate was used in the mixtures with the cyanamid, in part to neutralize the lime, and also to hold the nitrogen and ammonia which might be expelled by the lime of the cyanamid, as well as to retain the nitrogen and ammonia lost during ordinary fermentation processes. During the decomposition of calcium cyanamid in the soil the lime is gradually precipitated as carbonate, and this same process undoubtedly takes place in the manure. Acid phosphate, kainit, and gypsum are quite extensively recommended for the purpose of preserving manure. Commercial acid phosphate contains about 14 per cent of available phosphoric acid; kainit contains approximately 12.5 per cent of potash, and cyanamid contains 20 to 22 per cent of ammonia. It is accordingly evident that when the above mixture is applied to manure the three essential fertilizing elements are added in considerable amounts, and if acid phosphate is used in a ratio of 6 or 8 to 1 no loss of ammonia will result, but the nitrogen and ammonia which escape during the normal fermentation of manure will be retained.

THE COST OF EFFECTIVE FERTILIZER MIXTURES.

Under normal conditions kainit sells for $12 to $14 per ton, making the cost about two-thirds of a cent a pound. Kainit is not available at the present time. Calcium cyanamid was quoted January 1, 1916, at $2.45 per unit of ammonia. Calculating the average percentage of ammonia present in cyanamid at 21 per cent, the cost per ton is $51.45, or 2.6 cents per pound in ton lots. Cyanamid is at present handled only in large amounts and by manufacturers of mixed fertilizers. It requires only the demand to make it available in all parts of the country. During the fall of 1915, several lots of acid phosphate were purchased, and the average price, when purchased in hundred-pound lots, was 1 cent per pound. It was quoted at $14 per ton January 1, 1916. Four pounds of the calcium cyanamid and 4 pounds of acid phosphate, as seen in Table 6, series 4, showed an effective larvicidal action. The cost of this mixture was 14½ cents per 8 bushels of manure, or 1.8 cents per bushel. In Table 6, No. 4, the results also show that a mixture composed of 3 pounds of calcium cyanamid and 6 pounds of kainit gave an effective larvicidal action. The cost of the treatment in this case was 1½ cents per bushel. In the experiments in cages and in boxes mixtures containing 1 pound of the cyanamid and 2 pounds of acid phosphate per 8 bushels have given satisfactory results. The cost in this case was one-half cent per bushel.

From these figures it appears that the fertilizer mixtures applied in sufficient amounts to act as effective larvicides on open piles are more expensive than borax or powdered hellebore. However, in the former treatment the fertilizing value of the manure is greatly increased, and when considered from this point of view the actual larvicidal cost of the fertilizer mixtures is materially lessened.

THE AMOUNTS OF MANURE TREATED WITH FERTILIZER MIXTURES TO APPLY TO THE SOIL.

One hundred and fifty pounds of calcium cyanamid per acre is stated by Pranke (6) to be the most economical amount to apply to the soil at one time. When manure is treated in boxes or pits at the rate of 1 pound of calcium cyanamid and 2 pounds of acid phosphate per 8 bushels (10 cubic feet) of manure, taking the weight of 8 bushels of fresh manure at 120 pounds, it is calculated that 16⅔ pounds of calcium cyanamid and 33 pounds of acid phosphate will be present per ton of fresh manure. If it is desired, kainit may be used in place of a part of the acid phosphate in the mixture. Manure treated in this manner and applied to the soil at the rate of 9 tons per acre will furnish 150 pounds of calcium cyanamid, which is mentioned above as being the most economical application of the cyanamid. The application of more than 9 tons per acre would be uneconomical.

When piles of manure are treated with a mixture containing 4 pounds of calcium cyanamid and 4 pounds of acid phosphate, these two substances are added to the manure at the rate of 65 pounds per ton. As above, the weight of fresh manure is taken at 15 pounds per bushel. The manure treated with this mixture should be applied to the soil at the rate of only 2½ tons per acre.

In connection with the use of cyanamid as a fertilizer, the following statements of E. J. Pranke (6) are of interest:

> Since cyanamid is a medium slow-acting fertilizer, it should be applied to the crop not less than 70 to 80 days before the harvest, in order that the nitrogen may be completely utilized by that crop. Experience has shown that the most economical utilization of a nitrogen fertilizer is in conjunction with the other fertilizer elements, phosphorus and potash. For this reason it is recommended that cyanamid be used as a part of a fertilizer mixture rather than it be applied alone.
>
> If cyanamid is to be applied to very acid soils, such soils should be put in a productive condition by judicious liming sometime before the application of the fertilizer. The application of barnyard manure will help to establish the bacteria that are deficient in such soils.

EXPERIMENTS WITH BORIC ACID AND SULPHUR.

BORIC ACID, $B(OH)_3$.

Two open-pile experiments were carried out, using solutions of boric acid, one-fourth pound to 5 gallons of water, and applying the same to 4 bushels of manure. The tests showed a 97.4 per cent and a 99.8 per cent larvicidal action. Boric acid was quoted wholesale January 1, 1916, at 10 to 10½ cents per pound for commercial grade. Based on the price just quoted, the cost of treating manure with boric acid, judging from these two tests, was five-eighths cent per bushel of manure. It is probable that somewhat smaller amounts of boric acid than one-half pound per 10 gallons of water may be effectively employed. Borax cost, January 1, 1916, from 5¾ to 6 cents per pound wholesale, or 4 cents for two-thirds of a pound, a quantity sufficient to destroy all the maggots in 8 bushels of manure. The cost was therefore one-half cent per bushel of manure. It is apparent that boric acid is equally effective as borax as a larvicide, but it has not been determined whether there is any difference in the action of these two substances on plant growth, although from the few tests reported in the literature no differences are indicated.

SULPHUR.

One box test in which one-third of a bushel of manure and 5⅓ ounces of flowers of sulphur were used was carried out at the suggestion of Prof. C. V. Piper. A control was employed, both samples being moistened and a large number of fly eggs added to each. Forty-two flies emerged from the box treated with sulphur and 909 flies from the control. The application of 1 pound of sulphur per bushel of manure is a large one, and, if used on a large scale, would not only involve considerable expense, but would undoubtedly have an injurious action on plants when applied to the soil.

SUMMARY.

During the fly season of 1915, the larvicidal action of infusions of 18 plant materials was tested. None of these, with the exception of hellebore, were sufficiently economical and effective to be classed as practical larvicides; Berberis, Cinchona, and larkspur in the amounts employed showed some larvicidal action.

Various mixtures of calcium cyanamid, acid phosphate, kainit, and gypsum were tested.

One pound of calcium cyanamid in mixtures with 2 to 4 pounds of acid phosphate proved effective in cages and boxes where the surface exposure of the manure was approximately 4 square feet.

A similar mixture may prove effective in pits. In both cases the treatment should be based on the number of square feet of exposed surface of the manure. The cost of this treatment, based on wholesale prices January 1, 1916, is approximately 1.4 cents per square foot.

In several open-pile experiments calcium cyanamid applied in mixtures with acid phosphate or kainit at the rate of one-half pound per bushel of manure showed an apparent larvicidal action of 98 per cent. By using a mixture composed of calcium cyanamid, acid phosphate, and kainit, the three essential plant elements, nitrogen, potash, and phosphoric acid, are added to the manure. The nitrogen and ammonia which usually escape from untreated manure piles will be retained if sufficient acid phosphate is used, and the fly maggots will be killed at the same time. The cost of this treatment, in which one-half pound of calcium cyanamid and one-half pound of acid phosphate are applied for each bushel of manure, is 1.8 cents per bushel.

SUMMARY OF THREE SEASONS' WORK.

From the three seasons' work it appears that borax used at the rate of two-thirds of a pound per 10 gallons of water and sprinkled over 8 bushels of manure is the least expensive and the most effective larvicide. Caution should be used in treating manure to be employed for agricultural purposes, because of the injurious action on plant growth of excessive applications of borax. It is, however, recommended for the treatment of all manure not to be used for agricultural purposes, for refuse piles of all kinds, stable floors, etc. The cost of the borax treatment, when borax sells for 8 cents per pound, is one-half cent per bushel.

Powdered hellebore, using one-half pound per 10 gallons of water, and applying the same to 8 bushels of manure, is an effective larvicide and without action on plant growth. The cost[1] is variable. On

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[1] It is unusually difficult to give a fair retail price for these substances because of the advance in price of chemicals and fertilizers. Borax was quoted retail Washington, D. C. at 8½ to 12 cents per pound in 100-pound lots; powdered hellebore, in 100-pound lots, at 35 cents per pound; acid phosphate $1.75 to $2 for 167-pound sacks. Kainit is not obtainable at the present time; the usual price is $12 per ton, or three-fourths to 1 cent per pound in 100-pound lots. Calcium cyanamid is manufactured by but one company in North America, although there are several companies producing it abroad. This American company does not ordinarily sell calcium cyanamid in less than carload lots. The price was $51.45 per ton f. o. b. Niagara Falls, Ontario. The figures just given were those quoted on March 1, 1916. Calcium cyanamid is handled by manufacturers of mixed fertilizers.

January 1, 1916, the wholesale price was 16 to 17 cents per pound, but it should be obtained in large amounts under ordinary conditions at 11 to 12 cents per pound. The cost of treating manure with solutions of powdered hellebore, when it sells for 17 cents per pound, is therefore 1 cent per bushel.

Solutions of aniline and emulsions of nitrobenzene with fish-oil soap, reported in Department Bulletin 245 (2), also proved to be effective larvicides, and did not injure the manure, as far as could be determined by chemical and bacteriological examination.

The indications are that calcium cyanamid, acid phosphate, and kainit mixtures can be used as effective larvicides, if one-half pound of calcium cyanamid is present in the mixture per bushel of the manure treated. The cost of applying a mixture of one-half pound calcium cyanamid and one-half pound acid phosphate per bushel of manure is 1.8 cents per bushel, but this is materially lessened by the increased fertilizing value of the treated manure.

Among the other substances which have been found effective in reasonable amounts, but can not be recommended because of their extremely toxic action, are potassium cyanid, Paris green, arsenic dip, and pyridine.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 409

Contribution from Office of Markets and Rural Organization,
CHARLES J. BRAND, Chief

Washington, D. C. ▼ August 26, 1916

FACTORS AFFECTING INTEREST RATES AND OTHER CHARGES ON SHORT-TIME FARM LOANS.

UNIVERSITY OF ILLINOIS LIBRARY
SEP 25 1916

By C. W. THOMPSON,
Specialist in Rural Organization.

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INTRODUCTION.

There are wide variations in the interest rates and other charges paid on short-time loans by farmers in different sections of the United States. The extent of the variations between States is indicated by the diagram, Plate I, which shows for each State the average interest rate and the average total cost for loans to farmers on personal security, as obtained from reports received by the Office of Markets and Rural Organization. Variations inside the State boundaries are shown by the table on page 3, which gives the same averages for districts or subdivisions within the States. The districts referred to in this table are shown on the map, Plate II.

The extent to which extra charges of one kind or another affect the cost of short-time loans to farmers is indicated by the diagram and the table. It will be seen that these charges are especially high in the Southern and the Rocky Mountain States. The relatively large

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NOTE.—This bulletin discusses the reasons for variations in interest rates on short-time farm loans, giving special attention to those causes of variation which can be modified by individual or collective action.

figure shown for extra cost in North Carolina is due, in part, to the fact that with a legal interest rate of 6 per cent the lenders of that State have made up in extra charges what the State law does not permit them to charge as interest. In some cases the difference between the interest rates shown in the table and the estimated total cost may be explained by the fact that interest is reckoned for a full year on a loan which actually runs for only 9 or 10 months, though more often the extra charge takes the tangible form of a bonus demanded by the loan agent in payment for his services in "getting the money" or of a fee for making out the papers. Especially in connection with loans on chattel security is there likely to be considerable expense for making out papers, recording the chattel mortgage, etc. In general, however, the extra charges are small where the interest rates are low, and vice versa, so that the variations between different sections of the country may be considered either on the basis of the nominal interest rate alone or on the basis of the total cost.

No simple explanation will account adequately for these variations between one State or district and another. While some of the factors involved are essentially natural conditions and are not readily subject to change, others have been brought about primarily by human agencies and may be modified considerably through voluntary action. It is realized that any improvement in the farm-loan situation must be secured mainly through the modification of conditions controlled by human agencies. Therefore, while some attention should be given to natural conditions in order to show their importance as factors affecting interest rates and other charges on short-time loans, the purpose of this discussion is primarily to show some of the ways in which conditions actually are being modified so as to enable the farmer to obtain better terms.

IMPORTANCE OF NATURAL CONDITIONS.

Climate, contour of the land, and soil are, for the most part, natural conditions and, in the order mentioned, exert a relatively permanent influence upon the interest rates and other charges on short-time loans. Soil and to a less degree contour are subject to modification as the result of human activity. Much of our soil has been impoverished through a continuous one-crop system. Sandy hillsides, through open cultivation, often have been washed into gullies.

Because of the relative permanency of climate, contour, and soil it is necessary to adapt farming methods and systems to these factors rather than to attempt any material modification in the natural conditions in the interest of any particular farming need. Through the influence which they exert on farming and the results of farm business, however, they become important factors indirectly affecting interest rates on short-time farm loans. The influence of

LOANS TO FARMERS ON PERSONAL SECURITY
AVERAGE RATES FOR INTEREST AND EXTRA CHARGES

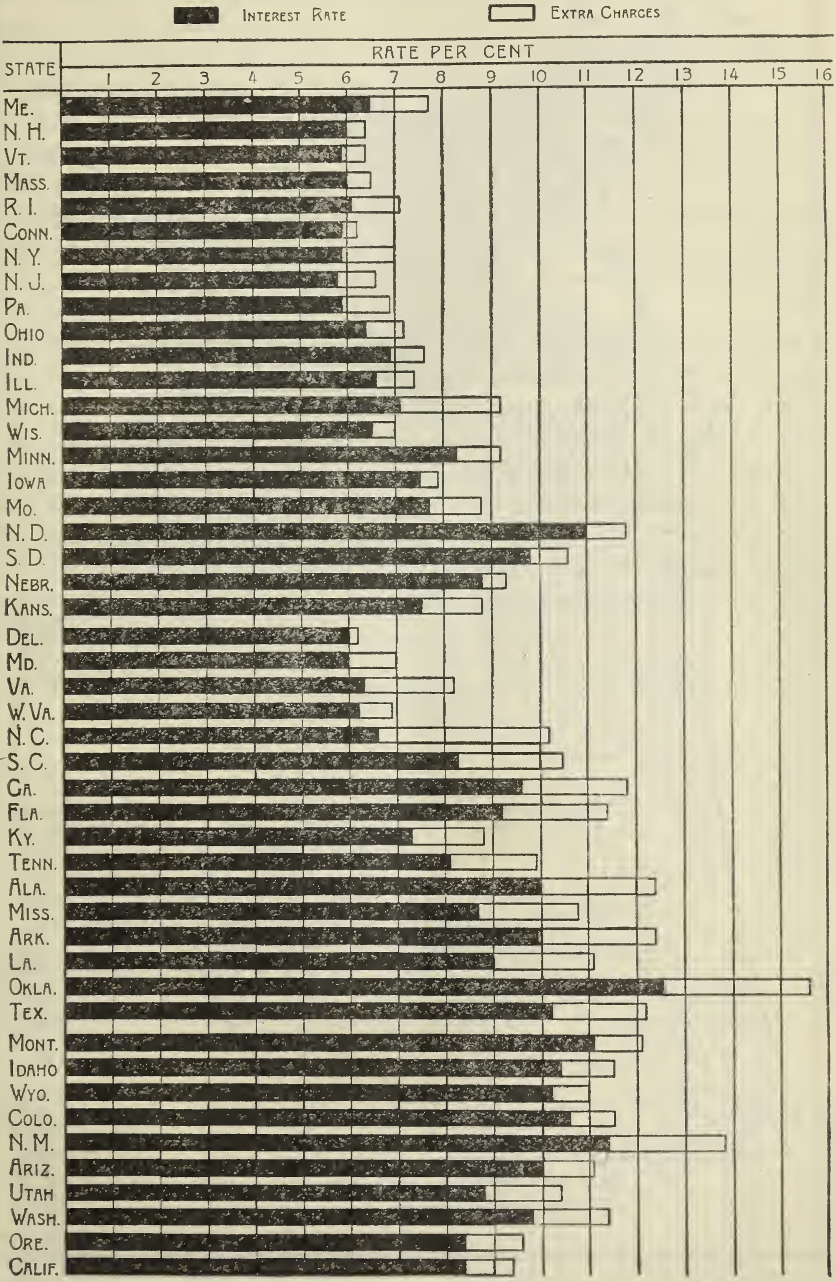

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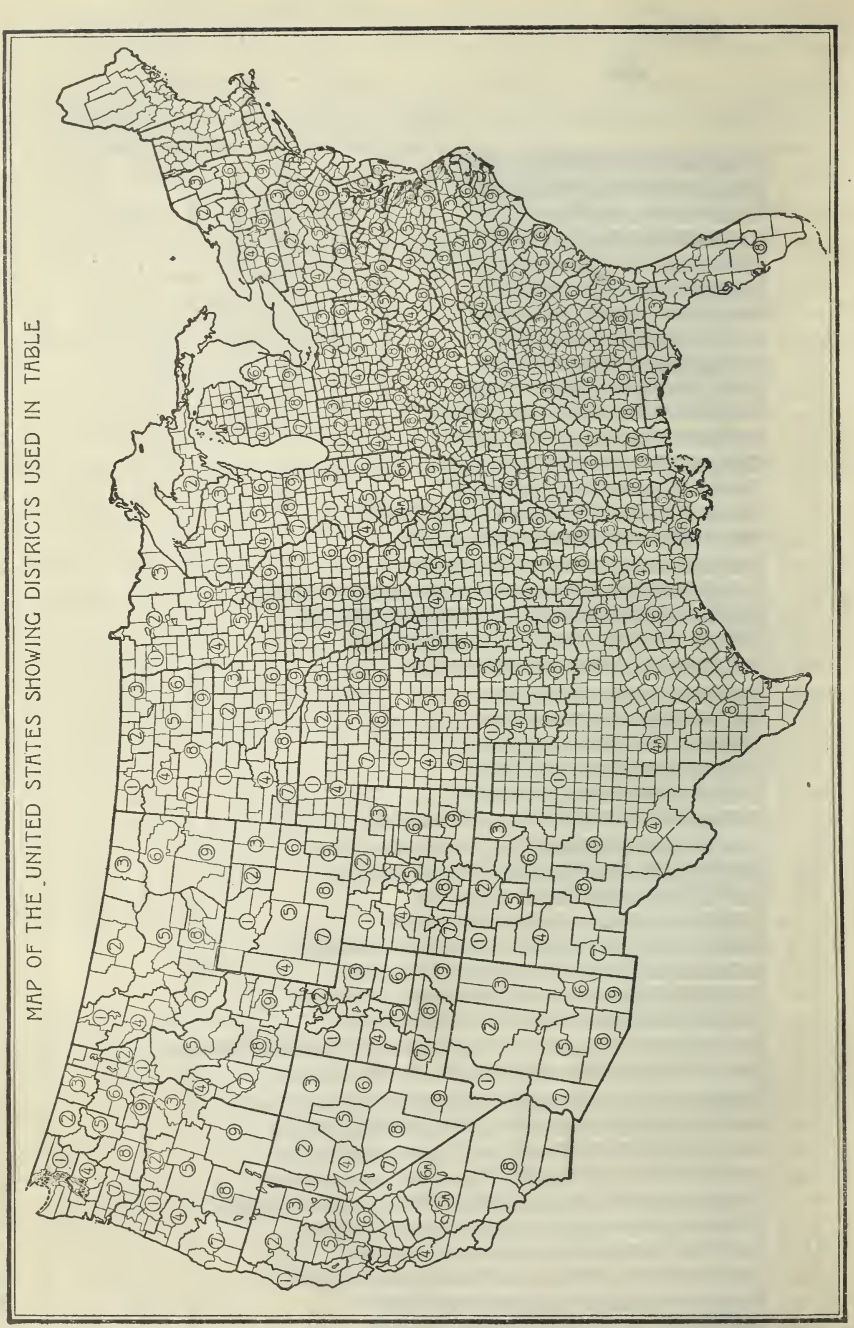
PLATE I.



MAP OF THE UNITED STATES SHOWING DISTRICTS USED IN TABLE

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PLATE II.

these factors may be noted in a comparison of the district averages for the cost of short-time loans as shown in the table below. The rapid rise in interest rates as one proceeds westward within the States of Kansas, Nebraska, South Dakota, and North Dakota illustrates clearly the effect of diminishing rainfall. The fact that the rates are lower in northern Illinois than in the southern part of the State is accounted for partly as the indirect effect of soil conditions, while the lower rates prevailing in the northwestern part of Minnesota (the valley of the Red River of the North) in contrast with those existing in the north-central part of the same State are indirectly explained as the effect of the soil and contour conditions of these regions.

While the effect of natural conditions on existing interest rates is thus apparent, and while the natural conditions themselves appear to be relatively permanent, it does not necessarily follow that interest rates must continue to vary to the extent shown in the table. For the disadvantages of certain natural conditions have been offset in some measure in certain regions by the adoption of farming methods and practices adapted to the given conditions. It is believed that, as a result of continued study and experiment, there may be further improvement of this character in regions where natural conditions are relatively unfavorable.

Loans to farmers on personal security—Average rates for interest and for total cost, by States and districts.

Geographic division, State, and district.	Loans on personal security.	
	Average interest rate.	Average total cost.[1]
NEW ENGLAND.		
Maine	6.5	7.7
New Hampshire	6.0	6.4
Vermont	5.9	6.4
Massachusetts	6.0	6.5
Rhode Island	6.1	7.1
Connecticut	5.9	6.2
MIDDLE ATLANTIC.		
New York	5.9	7.0
District 2	5.8	6.5
District 3	6.0	6.6
District 4	6.0	7.3
District 5	5.9	6.5
District 6	5.9	7.4
District 7	6.0	7.1
District 8	6.0	7.2
District 9	6.0	7.1
New Jersey	5.8	6.6
Pennsylvania	5.9	6.9
District 1	6.1	7.5
District 2	6.0	(2)
District 3	5.9	6.2
District 4	6.0	6.8
MIDDLE ATLANTIC—continued.		
Pennsylvania—Continued.		
District 5	5.8	6.6
District 6	6.0	7.8
District 7	5.9	7.4
District 8	5.6	7.1
District 9	5.7	6.4
EAST NORTH CENTRAL.		
Ohio	6.4	7.2
District 1	6.9	7.9
District 2	5.9	6.2
District 3	6.2	7.1
District 4	6.4	6.9
District 5	6.5	7.7
District 6	6.2	6.7
District 7	6.3	6.9
District 8	7.0	7.2
District 9	6.3	6.9
Indiana	6.9	7.6
District 1	7.1	7.5
District 2	6.9	7.9
District 3	6.4	6.6
District 4	7.3	8.2

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[1] Average of estimated total cost (rate per cent), including "discounts, bonuses, commissions, and any other extra charges," as reported by correspondents.

[2] Data at hand not sufficient to warrant the showing of a district average.

Loans to farmers on personal security—Average rates for interest and for total cost, by States and districts—Continued.

Geographic division, State, and district.	Loans on personal security.	
	Average interest rate.	Average total cost.[1]
EAST NORTH CENTRAL—contd.		
Indiana—Continued.		
District 5	6.7	7.5
District 6	6.4	6.9
District 7	7.3	8.3
District 8	7.0	7.9
District 9	6.6	7.5
Illinois	6.6	7.4
District 1	6.4	6.9
District 3	6.2	6.7
District 4	6.4	7.4
District 4a	6.6	7.3
District 5	6.3	6.8
District 6	6.7	7.4
District 6a	6.9	7.8
District 7	6.8	7.7
District 9	7.4	9.3
Michigan	7.1	9.2
District 1	7.8	9.8
District 2	7.3	8.7
District 3	7.9	14.1
District 4	7.0	10.7
District 5	7.9	11.2
District 6	8.4	10.8
District 7	6.7	8.1
District 8	6.5	7.3
District 9	6.5	7.4
Wisconsin	6.5	7.0
District 1	7.8	8.4
District 2	6.9	7.8
District 3	7.0	8.1
District 4	6.6	7.2
District 5	6.4	6.7
District 6	5.8	6.3
District 7	6.7	6.8
District 8	6.2	6.3
District 9	5.7	6.1
WEST NORTH CENTRAL.		
Minnesota	8.3	9.2
District 1	9.5	10.6
District 2	10.0	11.4
District 3	(2)	(2)
District 4	8.6	8.7
District 5	8.0	9.0
District 6	8.3	9.4
District 7	8.4	9.0
District 8	7.4	8.4
District 9	6.7	6.9
Iowa	7.5	7.9
District 1	7.9	7.9
District 2	7.7	8.2
District 3	7.1	7.8
District 4	7.9	8.2
District 5	7.2	7.4
District 6	6.8	7.4
District 7	7.7	8.7
District 8	7.7	8.2
District 9	6.9	7.2
Missouri	7.7	8.8
District 1	7.3	7.9
District 2	7.6	8.0
District 3	7.2	8.0
District 4	7.5	8.1
District 5	7.7	9.2
District 6	7.4	8.6
District 7	8.0	8.6
District 8	8.3	12.0
District 9	8.5	9.5
WEST NORTH CENTRAL—contd.		
North Dakota	11.0	11.8
District 1	11.6	12.5
District 2	11.6	12.3
District 3	10.3	11.3
District 4	11.4	13.2
District 5	11.2	12.0
District 6	9.6	9.7
District 7	11.5	12.2
District 8	11.1	11.7
District 9	10.2	10.6
South Dakota	9.8	10.6
District 1	10.7	12.4
District 2	9.9	11.4
District 3	9.5	10.3
District 4	10.1	10.6
District 5	9.8	9.9
District 6	8.7	9.1
District 7	11.3	12.3
District 8	11.6	12.4
District 9	8.5	8.9
Nebraska	8.8	9.3
District 1	9.8	10.2
District 2	9.8	10.4
District 3	8.5	8.8
District 4	9.8	10.6
District 5	9.0	9.1
District 6	7.7	8.3
District 7	9.5	10.4
District 8	9.2	9.9
District 9	7.8	8.3
Kansas	7.5	8.8
District 1	9.6	10.1
District 2	8.4	8.9
District 3	8.0	8.6
District 4	10.2	(2)
District 5	7.9	8.0
District 6	7.9	8.1
District 7	10.2	10.9
District 8	8.7	9.6
District 9	8.1	8.4
SOUTH ATLANTIC.		
Delaware	6.0	6.2
Maryland	6.0	7.0
District 1	6.2	7.4
District 2	6.0	6.4
District 3	6.0	6.4
District 5	6.0	8.0
District 6	(2)	(2)
District 8	6.0	7.5
Virginia	6.3	8.2
District 2	6.0	7.0
District 4	6.4	9.1
District 5	6.2	10.2
District 6	6.0	7.6
District 7	6.1	7.5
District 8	6.4	8.1
District 9	7.3	8.2
West Virginia	6.2	6.6
District 1	5.9	(2)
District 2	6.0	7.0
District 3	6.0	(2)
District 4	7.7	8.4
District 5	6.4	(2)
District 6	6.0	6.6
District 8	6.0	7.3

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[1] Average of estimated total cost (rate per cent), including "discounts, bonuses, commissions, and any other extra charges," as reported by correspondents.

[2] Data at hand not sufficient to warrant the showing of a district average.

Loans to farmers on personal security—Average rates for interest and for total cost, by States and districts—Continued.

Geographic division, State, and district.	Loans on personal security.	
	Average interest rate.	Average total cost.[1]
SOUTH ATLANTIC—contd.		
North Carolina	6.6	10.2
District 1	6.5	9.9
District 2	6.0	9.8
District 3	6.0	13.1
District 4	6.3	8.3
District 5	6.5	9.1
District 6	7.8	11.7
District 7	6.8	10.0
District 8	6.8	11.0
District 9	6.8	14.0
South Carolina	8.3	10.5
District 1	8.5	10.5
District 2	8.0	9.4
District 3	8.2	11.2
District 4	8.2	10.0
District 5	8.2	10.3
District 6	(2)	(2)
District 8	8.2	11.9
Georgia	9.6	11.8
District 1	9.9	12.1
District 2	8.7	11.5
District 3	8.6	10.8
District 4	9.8	13.1
District 5	10.4	11.8
District 6	10.0	12.9
District 7	9.2	11.0
District 8	10.5	11.8
District 9	8.0	11.4
Florida	9.2	11.4
District 1	9.5	11.6
District 3	9.3	11.4
District 5	8.9	12.4
District 8	9.1	9.8
EAST SOUTH CENTRAL.		
Kentucky	7.3	8.8
District 1	7.3	9.2
District 2	6.9	8.2
District 3	7.3	9.1
District 5	6.3	7.5
District 6	7.6	9.0
District 7	8.7	10.3
District 7a	7.2	9.2
District 8	7.0	8.4
District 9	8.1	9.3
Tennessee	8.1	9.9
District 1	8.9	10.3
District 2	7.9	9.8
District 3	6.6	8.8
District 4	10.4	11.1
District 5	7.6	9.0
District 6	(2)	(2)
District 7	9.5	13.1
District 8	7.4	8.8
District 9	8.0	8.7
Alabama	10.0	12.4
District 1	9.4	11.5
District 2	12.0	15.8
District 3	9.8	12.0
District 4	9.4	10.0
District 5	9.5	12.6
District 6	10.7	12.8
District 7	8.9	10.3
District 8	9.5	11.8
District 9	10.6	12.5
Mississippi	8.7	10.8
District 1	8.5	11.1
District 2	8.3	10.3

Geographic division, State, and district.	Loans on personal security.	
	Average interest rate.	Average total cost.[1]
EAST SOUTH CENTRAL—contd.		
Mississippi—Continued.		
District 3	8.6	9.5
District 4	9.8	11.8
District 5	8.9	13.5
District 6	8.1	10.1
District 7	8.5	10.4
District 8	8.6	11.2
District 9	8.3	9.7
WEST SOUTH CENTRAL.		
Arkansas	9.9	12.4
District 1	9.7	10.0
District 2	10.4	13.4
District 3	9.9	12.0
District 4	9.9	13.1
District 5	9.8	12.3
District 6	9.8	12.7
District 7	9.8	12.3
District 8	10.2	11.7
District 9	9.8	12.2
Louisiana	9.0	11.1
District 1	10.5	13.0
District 2	9.3	11.0
District 3	9.1	9.8
District 4	8.0	11.7
District 5	9.2	11.2
District 6	8.3	10.0
District 7	8.5	12.4
District 8	8.5	9.8
District 9	8.2	10.4
Oklahoma	12.5	15.6
District 1	11.2	14.6
District 2	10.4	11.4
District 3	12.1	11.5
District 4	12.2	16.5
District 5	12.7	16.0
District 6	13.8	19.2
District 7	12.2	15.4
District 8	13.2	16.6
District 9	14.4	18.2
Texas	10.2	12.2
District 1	11.1	12.7
District 2	10.2	12.8
District 3	10.9	13.9
District 4	10.0	10.9
District 4a	10.4	11.7
District 5	9.9	11.5
District 6	10.3	14.6
District 8	9.3	10.4
District 9	9.4	10.4
MOUNTAIN.		
Montana	11.1	12.1
District 1	12.0	15.0
District 2	11.3	12.3
District 3	11.4	12.0
District 4	11.3	12.5
District 5	10.8	11.5
District 6	11.6	13.7
District 7	(2)	(2)
District 8	11.3	12.5
District 9	10.3	10.4
Idaho	10.4	11.5
District 1	10.7	11.6
District 2	(2)	(2)
District 4	(2)	(2)
District 5	10.4	11.3
District 7	10.2	12.8

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[1] Average of estimated total cost (rate per cent), including "discounts, bonuses, commissions, and any other extra charges," as reported by correspondents.

[2] Data at hand not sufficient to warrant the showing of a district average.

Loans to farmers on personal security—Average rates for interest and for total cost, by States and districts—Continued.

Geographic division, State, and district.	Loans on personal security.		Geographic division, State, and district.	Loans on personal security.	
	Averarge interest rate.	Average total cost.[1]		Average interest rate.	Average total cost.[1]
MOUNTAIN—continued.			PACIFIC—continued.		
Idaho—Continued.			Washington—Continued.		
District 8	10.1	11.4	District 5	11.1	13.9
District 9	10.5	11.3	District 6	9.8	11.0
Wyoming	10.2	11.0	District 7	8.4	11.1
Colorado	10.6	11.5	District 8	9.7	10.8
District 1	10.3	10.7	District 9	9.8	9.8
District 2	8.4	8.8	Oregon	8.4	9.6
District 3	10.3	10.9	District 1	8.0	9.6
District 4	10.8	11.9	District 2	9.1	9.5
District 5	9.9	11.1	District 3	9.0	9.1
District 6	10.3	11.2	District 4	7.8	8.8
District 7	13.0	13.6	District 5	8.5	11.5
District 8	12.1	(2)	District 7	8.7	9.7
District 9	10.1	10.8	District 8	(2)	(2)
New Mexico	11.4	13.8	District 9	(2)	(2)
Arizona	10.0	11.1	California	8.4	9.4
Utah	8.8	10.4	District 1	7.3	9.4
			District 2	8.8	9.4
PACIFIC.			District 3	8.2	9.6
			District 4	7.9	8.6
Washington	9.8	11.4	District 5	7.6	9.1
District 1	9.3	13.2	District 5a	8.9	9.7
District 2	11.2	13.5	District 6	10.0	10.4
District 3	10.8	12.3	District 6a	(2)	(2)
District 4	9.0	10.5	District 8	8.4	9.4

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[1] Average of estimated total cost (rate per cent), including "discounts, bonuses, commissions, and any other extra charges," as reported by correspondents.

[2] Data at hand not sufficient to warrant the showing of a district average.

DISTANCE FROM FINANCIAL CENTERS.

The location of financial centers, which determines their distance from the borrowers in a given community, conforms to the localization of commerce and industry. The latter is generally governed by natural conditions. This means that distance from financial centers as a factor affecting interest rates is also relatively permanent, although to a less degree than in the case of climate, contour, and soil conditions. A study of the table on page 3, in connection with the accompanying map, shows that the averages for the cost of loans gradually rise as one proceeds outward from the leading financial centers. It is believed that variations in interest rates attributable to this factor can be considerably lessened, but the remedy for this appears to lie in institutional rather than individual effort.

CHARACTERISTICS OF THE BORROWER.

PERSONAL CHARACTER.

The borrower who is known to be a man of honesty and integrity and who shows ability and judgment in the conduct of his farm business will ordinarily command the confidence of his banker and obtain credit on terms relatively favorable for his class of loans, whereas the individual who is uncertain in his personal character, erratic in his judgment, and irregular in his business habits will be considered a less desirable risk and, if he obtains a loan at all, usually must pay a higher rate of interest. In any case, if credit is to be extended wisely it is just as important to discourage its use among those who can not be trusted as it is to grant credit to trustworthy borrowers who will use the borrowed money profitably and repay it promptly.

BUSINESS ABILITY AND BUSINESS HABITS.

Oftentimes the borrower may be honest and upright in his intentions, but may fail to appreciate the importance of being prompt in meeting his obligations. Possibly he thinks that a few days after the date of maturity is soon enough to make payment, and that a little delay is unimportant. He may not stop to consider that extra work and expense are involved when notice must be given of overdue paper, or that bank examiners do not take kindly to notes that are overdue.

Again, the business ability and business habits of the farmer are tested when the banker asks for a statement of the borrower's business. This information is needed by the banker as a basis for intelligent rating. If the borrower is in the habit of keeping accounts and can explain the nature of his resources and liabilities and thus indicate accurately his financial standing, the wisdom of granting a desired loan as well as the proper terms thereon readily can be determined. On the other hand, if this information is lacking and the banker is in doubt about the safety of a particular loan, he is likely to charge up his uncertainty to the borrower's account in the form of a higher rate of interest.

The requirement that a borrower shall submit a statement of his business is being applied by bankers in their dealings with merchants and manufacturers. Accordingly, business men in general have become more or less familiar with this requirement, and are prepared to furnish such a statement whenever it is called for. Some bankers, in inaugurating a similar plan in connection with their farm loan business, are supplying farmers with especially prepared blanks, or rate sheets, on which the farmers furnish the desired information.

METHOD AND CHARACTER OF FARMING.

One important purpose of the rate sheet is to show how far the farmer devotes his energies to raising a single crop, or how far he diversifies his farming and gives attention to the raising of foodstuffs for his family and feed for his animals. If, for example, farmer A has a garden and raises enough vegetables and fruit to supply the family needs, if he keeps enough poultry, pigs, and other live stock to meet the requirements of his household for eggs, meat, milk and butter, if he provides enough pasture, hay, and fodder to feed his live stock, he has this advantage, that when the cash crop, whether cotton or grain, is ready for sale in the fall, it is not tied up with a lien to meet a season's advance for food or feed. He is in a position, therefore, to sell his cash crop whenever the marketing conditions are favorable. The relatively favorable position of such a farmer assists him in commanding the confidence of lenders.

On the other hand, consider farmer B, who comes to the local merchant and makes credit purchases of bacon, cornmeal, and canned goods for table use, and who goes back to his farm with a bale of hay or a sack of feed in his wagon box. In his cotton field there are patches where the yield is poor because of low soil fertility and indifferent methods of cultivation. The only enterprise on the farm is cotton growing and this crop is mortgaged in advance to supply the food and feed purchased in town and consumed on the farm. Farmer B has little if any credit at the bank. He gets a limited store credit on an advancing basis from a local merchant. His is the most expensive kind of credit and probably he is the farmer who is the least able to pay for it.

RESPONSIBILITY FOR THE ONE-CROP SYSTEM.

In some regions the lender even more than the farmer is responsible for the continuance of a one-crop system of farming. This is especially true where bankers refuse to extend credit to farmers except on the basis of a single crop, such as cotton in the South or a cereal crop in the North. Such a mistaken policy can be corrected only to the extent that the banker realizes the evil effects of one-crop farming and undertakes to cooperate actively with the farmer in the extension of credit on a proper basis.

It is scarcely possible to lay too much emphasis upon the practical importance of the method and character of farming as a factor affecting interest rates on farm loans. Every agricultural region has its own peculiar problems of adapting farming methods and practices to local conditions. There are progressive bankers in various parts of the country who realize the importance of cooperating with the farmers in promoting the kind of farming that will be permanently beneficial to the community. This suggests a common interest between bankers and farmers which should be made the basis for further cooperative effort.

CHARACTERISTICS OF THE LOAN.

As the importance of promoting and encouraging improved systems of farming becomes increasingly apparent, attention will be directed more and more toward such questions as the purpose and size of farm loans. How are the proceeds of a proposed loan to be employed? Are they to be expended for a productive purpose, such as would lead to improvement in the farming business? Is the size of the loan well adapted to the purpose in view? Does the period for which the loan is to run conform to the time the capital is actually needed? All of these questions have a direct bearing on the costs of short-time farm loans.

PURPOSE OF THE LOAN.

The use of any given loan ought to yield a return sufficient at least to repay both interest and principal. If the returns are not sufficient for this purpose, then the money should not be borrowed. The only way in which the use of credit can be directed so as to serve the interests of improved agriculture is to control the extension of loans so that they may be used for productive purposes only. This means, at the same time, a safer use of credit.

In some localities banks offer loans to farmers at reduced rates of interest when the money borrowed is used for some specific and approved purpose, such as the purchase of live stock, the building of silos, or the making of other improvements which will make farming more profitable under the given conditions.

SIZE OF THE LOAN.

The banker usually charges a higher rate of interest on a small loan than on a large one. The clerical and bookkeeping expenses are the same in both cases. Unless a higher rate were charged on small loans, the point would be reached where the expenses connected with such loans would be greater than the interest. On the other hand, it pays the banker to handle large loans at a lower rate of interest.

The importance of restricting loans to those for approved productive purposes and of having the size of the loan conform to the requirements of sound farm investment has been recognized by some bankers to such an extent that they employ advisers who discuss such questions with their farmer patrons in order to promote the interests of their farm-loan business. This plan has been followed by banks in the Central West, in New England, and in the South. The plan of one of the southern banks may be taken as an example. The agricultural adviser employed by this bank, after a conference with the prospective borrower, decides whether the proposed loan is businesslike and expedient. If the purpose of the loan meets with his approval, he works out a plan of procedure with the farmer. The farmer may consider that he needs a loan of $1,000. As a result of his conference with the adviser it may be found that $700 is sufficient. They discuss the safety of the proposed investment, the additional equipment necessary, and in case live stock is to be purchased, the crop rotation that will furnish the most economical supply of feed. These items are all arranged and agreed upon before the bank makes the loan. After the loan has been made and the capital invested it is the duty of the adviser to visit the farm from time to time to see if the plan adopted is adhered to and if the investment is yielding proper results. Such a plan means added protection to both the farmer and the banker.

RELATION OF THE FARMER TO THE LOAN AGENCY.

The banker often makes a difference in his interest charges between the regular patron and the man who is not a regular patron, other conditions being equal. If it is a question of favoring the one or the other, the banker generally favors his patrons. The farmer, therefore, who desires credit on favorable terms at a bank usually finds it important to establish banking connections by opening a checking account. In this way he becomes familiar with banking methods and with the general banking requirements for the extension of credit. A farmer who maintains this direct relation with his bank will understand something of the need for a definite basis for his financial rating, and will realize the importance of keeping farm accounts so that he can make a fairly definite showing of his resources and liabilities and of his farm income. The value of this realization can not be emphasized too strongly, in view of the fact that relatively few farmers keep accounts sufficient to give them a knowledge of their farm income, partly because of lack of training and partly because of a disinclination for this kind of work. Moreover, many farmers are occupied so completely with other duties that they feel they have little time to keep accounts.

Attempts are being made to overcome these difficulties in various ways. In one rather thickly settled farming region in Massachusetts, for example, the farmers have hired a bookkeeper cooperatively, who visits the farms and keeps the farm accounts. In certain States a plan has been adopted whereby the banker virtually becomes a bookkeeper for the farmer. Under this plan the farmer agrees to deposit all his receipts with the bank and to make all his payments by check. The farmer's deposit slip shows the source and character of each item, and there is a space on each check in which to indicate the purpose and character of the expenditure represented. Under this plan the banker is in a position to send the farmer a fairly complete monthly statement of his receipts and disbursements.

HOW COLLECTIVE ACTION AMONG FARMERS MAY IMPROVE THEIR RELATIONS TO LOAN AGENCIES.

In some parts of the country where farmers, if they obtained loans at all as individuals, were compelled to pay very high rates of interest, plans have been tried out under which groups of farmers have been able collectively to establish improved relations with banks. In several localities of the Central Western and Rocky Mountain regions, farmers have formed temporary agreements under which they act collectively as guarantee associations for approved loans of members. The added security from these associations has enabled members to obtain loans at reduced rates of interest. Another plan, illustrated by what has been done in a Texas community, involves a temporary agreement between a group of farmers and a bank, but differs from the plan previously mentioned in that the added security consists of a reserve fund left with the banker. Each borrower allows the bank to retain 5 per cent of his loan for a reserve fund, which is held as a guarantee for all the loans made under the agreement and is returned to the farmers at the termination of the agreement.

Under another plan, which has been employed in several communities of the Northwest, a group of business men agree to deposit a sum of money with a bank and guarantee the loans given to farmers for some specific and approved purpose. In all such cases farmers have been enabled to obtain credit on more favorable terms than usual.

HOW THE COOPERATIVE CREDIT ASSOCIATION HELPS MEMBERS TO OBTAIN LOANS ON BETTER TERMS.

In a number of localities in this country, groups of farmers have organized cooperative credit associations or credit unions. Usually each credit union makes definite arrangements with some bank by which the latter acts as a depositary and furnishes loans on specified terms. Thus one of the unions in North Carolina receives 3 per cent interest from its bank on deposits subject to check and 4 per cent on savings accounts left on deposit three months or longer, and pays 5 per cent interest on its loans from the bank. The credit union in turn pays its own members 4 per cent on their savings accounts and furnishes them loans at 6 per cent. Such a credit union not only accustoms its members to the use of check and savings accounts but also enables the members to obtain loans for approved productive purposes on better terms than they could obtain elsewhere.

ATTITUDE OF THE LOAN AGENCY TOWARD THE FARM-LOAN BUSINESS.

In many regions the banks are not accustomed to dealing with farmers to any extent, especially with tenants and croppers, and the latter, therefore, must obtain their loans from other sources. This is especially true in the cotton States, where the system of advances from merchants to farmers still prevails. A few banks are breaking away from this traditional attitude, however. In one community of South Carolina the banks are actively soliciting business with croppers and renters as well as with farm owners. One of these banks began this policy 15 years ago on the assumption that many small accounts of this character properly scattered would be safer for the bank than a few large accounts. The experience of these banks has led them to become more active than ever in the extension of their farm-loan business, while the farmers of their vicinity generally are obtaining loans on better terms than those living under similar agricultural conditions elsewhere.

It is realized that the farmers in some sections of the country are accustomed to carrying check accounts with banks and are as familiar with the requirements of banking relations as other business men. There are other regions, however, where many farmers have not had such experience in commercial matters and where the bankers could be of practical assistance in making the farmers better acquainted with banking methods. The banker should remember that the farmer is not subject to the periodic visits of an examiner, requiring that certain matters receive attention promptly within definite time limits. This is one reason why farmers do not always realize the importance of meeting their obligations on specified dates. One plan that has proved helpful in this connection is to have the banker give the farmer the benefit of ample written notice with reference to the maturity of interest or other payments.

Existing banking methods and practices as related to farm loans are often criticised by reason of the unwillingness or inability of certain bankers to carry over farm loans until the farmer is prepared to meet his obligations. Complaint is often heard of cases where a banker, with a little extra effort, could make arrangements to carry over the loan of some farmer patron, but where in fact an apparent indifference to the welfare of the farmer is shown. It is interesting to learn, however, that many bankers manifest exactly the opposite attitude, and use every resource at their command, including such assistance as they can obtain at larger financial centers, in order to carry over their farmer patrons until such time as payment on loans can be made conveniently.

Where banks are active in developing farm-loan business they realize the importance of understanding the requirements of safe and progressive agriculture and also the importance of educational work among farmers in the interest of improved agriculture. Such knowledge gives the banker a better understanding of the merits of farm loans and at the same time tends to raise the standard of farm-loan paper. These considerations not only make possible a safer and larger loan business for the banker but also lead to a decrease in the interest rates paid by the farmer.

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VALUE TO FARM FAMILIES OF FOOD, FUEL, AND USE OF HOUSE.

By W. C. FUNK, *Scientific Assistant.*

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The aim of this bulletin is to determine the value of those things which the farm furnishes to the farm family without money cost, namely, the use of a house, food, and fuel. To this end data were secured from nearly 1,000 families, representing widely separated sections in 14 States. Figures were gathered covering the value of all food, fuel, and shelter, itemized to show what part was bought and what part was furnished by the farm. Data also were collected bearing on the value of household labor on the farm.

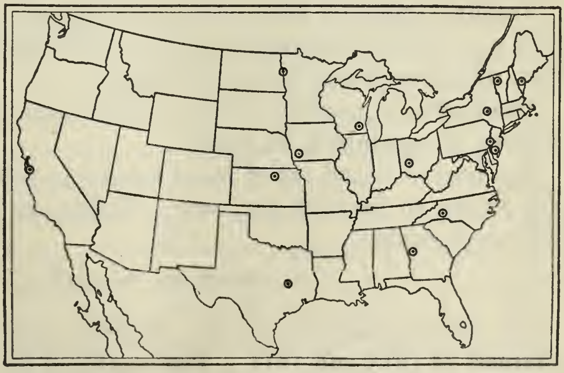

FIG. 1.—Map of United States, showing locations of areas studied.

FACTS BROUGHT OUT.

Following is a brief summary of the more significant averages established by this inquiry. The figures given are based on reports from 950 families, averaging 4.8 persons per family.

Annual value of food, fuel, and use of house—

Average per family, $642	Furnished by farm	$424 (66 per cent).
	Bought	218 (34 per cent).

Annual value of food—

Average per family, $448.	Animal products	58 per cent	From farm	58 per cent.
	Groceries	25 per cent	Bought	42 per cent.
	Vegetables	11 per cent		
	Fruits	6 per cent		

Annual value of fuel—

Average per family, $62.	Wood (9.4 cords)	$36.30	From farm	54 per cent.
	Coal (2.6 tons)	17.85	Bought	46 per cent.
	Oil (55 gallons)	6.33		

Annual value of use of house—

Average per family, $132.

Annual value of housework—

Average per family, $228	Furnished by family	$217 (95 per cent).
	Hired	11 (5 per cent).

It was found that the average annual value of meats (other than poultry) consumed per family was $107.25; of poultry products, $55.40; and of dairy products, $98.36. (The quantity of dairy products consumed was equivalent to 2,640 quarts of milk.)

Meats constitute the most important group of foods. As it increases relative to the other groups the total value of food consumed per family increases. Those families having a relatively greater consumption of either groceries, vegetables, or dairy products use relatively less meats, and their total consumption of food is less in value.

Families living on their own farms reported higher consumption of food and a larger proportion of food derived directly from the farm than did those living on rented farms.

The average quantity of fruit canned annually per family was 122 quarts; of vegetables, 32 quarts.

The cost of board (as of hired hands) in food, fuel, and housework was shown to be $129 per year. Thirty-one per cent of this represents cash outlay.

SOURCES OF DATA.

The data presented in this bulletin were collected during the summers of 1913 and 1914. The results of the 1913 study have been published in Farmers' Bulletin 635, What the Farm Contributes Directly to the Farmer's Living. In that study records were taken from 483 farm families distributed over 10 areas in as many States. Four additional areas were visited during the summer of 1914. A greater number of families per area were visited in this study than in that of 1913, thus permitting more detailed analysis of the data. The data from all areas are included in the tables only where the number of records were sufficient to do justice to the study.

A study of this kind is merely indicative in nature; no two families are alike in their tastes or financial ability to purchase what is most desired. Weather and other conditions limit the quantity and quality of products furnished by the farm for family use. The average of a large number of families is thus the best measure of the consumption per person or per family of food and fuel and the proportion of these furnished by the farm.

The data were obtained by the survey method, the enumerators being experienced men trained in that particular line of work. Few families keep an account of expenditures for household purposes or a record of products taken from the farm for house use; but careful questioning enables the enumerator to secure fairly accurate data.

REGIONS STUDIED.

Data were collected in 10 different areas in the year 1913. The three cotton-growing areas visited were in Gaston County, N. C.; Troup and Meriwether Counties, Ga.; and McLennan County, Tex. The types of agriculture in the North Carolina and Georgia areas were fairly similar, cotton and corn being the main crops. In the Texas area, however, a definite rotation of corn, oats, and cotton is followed. Farming is here done more extensively. The annual rainfall is considerably less than in the other two cotton-growing areas visited. Cloud County and Montgomery County, both important corn-growing districts, were selected for the work in the States of Kansas and Iowa, respectively. The chief crops grown in the Kansas area are corn, wheat, and alfalfa, though some farmers raise only corn and alfalfa. A series of dry years has discouraged the growing of all but a few vegetables. In the Iowa area the agriculture is more diversified, considerable oats and wheat being grown. Hog raising is an important industry in both these sections. The Jefferson County, Wis., area is wholly a dairy section. The money crops raised are oats and barley. Considerable pure-bred Holstein and Guernsey live stock is raised here. General farming is the prevailing type in Champaign County, Ohio, and in Bucks County, Pa. Corn, oats, wheat, and hay are the principal crops, with small dairies on many of the farms. In Otsego County, N. Y., and Lamoille County, Vt., dairying is the chief enterprise. The growing seasons here are appreciably shorter than in any of the other areas.

In 1914 more specialized sections in New Jersey, Maine, North Dakota, and California were visited. The New Jersey area in Gloucester County was distinctly market gardening or trucking. Much of the produce was hauled by the farmer to Philadelphia, a distance of about 10 miles, affording a good opportunity to buy household supplies. Vegetables and fruits were raised in great variety.

The Maine areas in Androscoggin and Oxford Counties were dairy and fruit regions. Apples and dairy products were the important farm sales. Considerable sweet corn was also grown for canning purposes. In North Dakota, Cass County was visited. Grain growing is the chief industry there. The farms are large and the distance to market relatively great. Practically no fruit is raised, and the variety of vegetables grown for home use is small. The region studied in Santa Clara County, Cal., is an irrigated fruit area. The farms are small and most of the area is devoted to fruit. The most generally grown fruits are prunes, apricots, and peaches. On many of the small farms all the land is devoted to fruit trees, no land being set aside even for the family garden. A garden to be successful has to be irrigated at frequent intervals, which is not always convenient with their present equipment, since the orchards are generally irrigated only once or twice a year.

THE FARMER'S INCOME.

The income received by the average farmer is not great. Studies which have been carried on in different States would indicate that the average labor income[1] of farmers falls considerably below $600 a year.[2] It must be remembered, however, that the average American farmer who is operating his own farm has nearly $5,000[3] of his own money invested in his farm business. In addition to his labor income he has the interest on this capital, while a large proportion of his needs are met directly by the farm.

THE FARMER'S LIVING.

In this discussion only those items of the farmer's living expenses have been included which may be wholly or partly furnished by the farm. An attempt is here made to determine the income the average farmer derives from this source. Upon the size of this direct income depends, to a large extent, the amount of cash the farmer has for clothing, recreation, education, incidental expenses, and saving.

The total average value of the three items of food, fuel, and use of house for the 950 farm families studied in this investigation (Table I) is $642, and 66 per cent, or $424, of this is furnished by the farm. The area in which the value of these items was the greatest was in Cass County, N. Dak., where the total was $948 per family, 61 per cent of which was furnished by the farm. The average family in this region was large, being 6.2 persons.[1] In Gaston County, N. C., the total was only $504, 85 per cent of which was furnished by the farm. The average number of persons to a family here was only 4.5. Table I gives these values for all areas visited, with the number of families visited in each section and the average acreage of the farms operated by these families.

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[1] Labor income: The amount that the farm operator has left for his labor after the farm expenses and 5 per cent interest on the average capital invested are deducted from the farm receipts. It represents what he earned as a result of his year's labor after the earnings of his capital have been deducted. It does not include the value of the use of the house or the fuel and food products furnished directly by the farm for family use.

[2] U. S. Department of Agriculture, Bureau of Plant Industry Circulars 75 and 132, Bulletins 41 and 117. N. Y. Cornell Bul. 295. Mo. Agri. Exp. Sta. Bul. 121.

[3] U. S. Census, 1910, Equity per farm.

TABLE I.—*Average annual value of food, fuel,*[a] *and use of a dwelling for 950 farm families.*

Location of regions in which study was made (county and State).	Number of families.	Persons per family.	Average per farm.			
			Acreage.	Food, fuel, and shelter furnished by the farm.	Food and fuel bought.	Total.
Oxford, Me	148	4.5	112	$355	$244	$599
Lamoille, Vt	49	4.8	130	349	177	526
Otsego, N. Y	55	4.0	118	431	210	641
Bucks, Pa	43	5.2	77	383	225	608
Gloucester, N. J	126	4.7	69	445	345	790
Gaston, N. C	55	4.5	86	428	76	504
Troup, Ga	50	5.4	102	520	110	630
McLennan, Tex	44	5.3	133	363	254	617
Champaign, Ohio	44	4.1	175	451	156	607
Jefferson, Wis	46	4.2	86	375	173	548
Montgomery, Iowa	51	4.4	161	485	183	668
Cloud, Kans	46	4.5	152	426	178	604
Cass, N. Dak	109	6.2	453	578	370	948
Santa Clara, Cal	84	4.9	45	341	357	698
All families	950	4.8	136	424	218	642

[a] Fuel includes oil used for both cooking and lighting.

Wherever the income upon which any family depends fails to maintain a fair standard of living, the elements of subsistence which are the last to be sacrificed are those which are most vital to health and happiness—food, fuel, and shelter. For the farm families visited the farm supplied nearly two-thirds of these items, and, if necessity demanded, the proportion could be made considerably greater.

Table II shows the value of the food, fuel, and house rent furnished by the farm. The average value of these items per family is $423.58, or $89.71 per person. Sixty-two per cent of this is food, 7 per cent fuel, and 31 per cent house rent.

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[a] In comparing the families on the different farms it will be found that they differ in number and age of persons. They must be reduced to a common basis to be comparable. Students of dietetics reduce all members of the family to the requirements of one adult man, assuming women and children of different ages to have certain definite relative capacity of consumption. In this study only two divisions were made—children of 12 years of age and under were counted as one-half an adult, and all persons over 12 years of age as adults. Farm labor and domestic help when boarded were counted as members of the family. In the discussion throughout the whole bulletin, wherever reference is made to size of family, it is in terms of adult equivalent.

TABLE II.—*Average annual value of food, fuel, and use of a dwelling furnished by the home farm (950 families).*

Location of regions in which study was made (county and State).	Food.		Fuel.		House rent.		Total.	
	Per family.	Per person.	Per family.	Per person.	Per family.	Per person.	Per family.	Per person.
Oxford, Me	$200.20	$44.49	$43.42	$9.65	$111.00	$24.63	$354.62	$78.77
Lamoille, Vt	192.43	40.10	63.40	13.21	93.00	19.38	348.83	72.69
Otsego, N. Y	189.60	47.40	53.80	13.45	188.00	47.00	431.40	107.85
Bucks, Pa	201.69	38.80	17.91	3.44	163.00	31.34	382.60	73.58
Gloucester, N. J	266.16	56.63	15.04	3.20	164.00	34.84	445.20	94.67
Gaston, N. C	330.65	73.47	41.87	9.30	56.00	12.45	428.52	95.22
Troup, Ga	376.03	69.65	51.60	9.56	92.00	17.04	519.63	96.25
McLennan, Tex	275.62	52.00	4.13	.78	83.00	15.66	362.75	68.44
Champaign, Ohio	248.28	60.57	30.50	7.44	172.00	42.00	450.78	110.01
Jefferson, Wis	209.44	47.60	35.80	8.14	130.00	29.54	375.24	85.28
Montgomery, Iowa	297.28	70.80	30.20	7.20	158.00	37.62	485.48	115.62
Cloud, Kans	292.48	65.00	17.97	4.00	116.00	25.80	426.45	94.80
Cass, N. Dak	384.58	62.03	18.04	2.91	175.00	28.21	577.62	93.15
Santa Clara, Cal	175.62	35.84	16.51	3.37	149.00	30.40	341.13	69.61
Average, all families	260.00	54.60	31.44	6.83	132.00	28.28	423.58	89.71

The distribution of the products bought is indicated in Table III. Food constitutes 86 per cent of the total and fuel 14 per cent. The item fuel includes coal, wood, and oil, oil being used for both fuel and lighting purposes. The big item of the products bought is food. The fact that the quantity bought per person varies from $16 to $66 in the different areas would seem to indicate that a material saving could be made in this group of products bought. In the New Jersey area, where the average value of food bought per person is relatively high, this quantity varies from $24 to $120 in a group of families of the same size, showing that a material saving could be made should necessity demand it. The fuel bought is not such a variable quantity within the same area.

TABLE III.—*Average annual value of the food and fuel bought (950 families).*

County and State.	Food.		Coal.		Wood.		Oil.		Total.	
	Per family.	Per person.	Per family.	Per person.	Per family.	Per person.	Per family.	Per person.	Per family.	Per person.
Oxford, Me	$226.76	$50.39	$6.39	$1.42	$2.98	$0.66	$7.65	$1.70	$243.78	$54.17
Lamoille, Vt	169.17	35.24	1.01	.21	2.00	.42	4.61	.96	176.79	36.83
Otsego, N. Y	186.71	46.68	16.00	4.00	1.00	.25	5.79	1.45	209.50	52.38
Bucks, Pa	190.32	36.60	26.90	5.17	1.09	.21	6.37	1.21	224.68	43.19
Gloucester, N. J	299.06	63.63	30.69	6.53	5.87	1.25	9.31	1.98	344.93	73.39
Gaston, N. C	71.28	15.85	....	....	1.71	.38	3.10	.69	76.09	16.92
Troup, Ga	104.42	19.32	....	....	....	....	5.18	.96	109.60	20.28
McLennan, Tex	213.47	40.30	17.35	3.27	15.17	2.86	7.58	1.43	253.57	47.86
Champaign, Ohio	124.98	30.50	23.70	5.78	2.00	.49	4.88	1.19	155.56	37.96
Jefferson, Wis	143.25	32.56	20.70	4.70	3.00	.68	5.78	1.31	172.73	39.25
Montgomery, Iowa	146.43	34.87	29.57	7.04	....	....	6.92	1.65	182.92	43.56
Cloud, Kans	157.41	34.97	12.70	2.82	.33	.07	7.21	1.60	177.65	39.46
Cass, N. Dak	279.00	45.00	62.00	10.00	20.71	3.34	7.94	1.28	369.65	59.62
Santa Clara, Cal	322.08	65.73	2.84	.58	26.07	5.32	6.32	1.29	357.31	72.92
Average, all families	188.17	39.40	17.85	3.68	5.85	1.14	6.33	1.34	218.20	45.56

FOOD.

Of the items furnished by the farm included in Table I, food constitutes 62 per cent, and of the items bought it constitutes 86 per cent. It is, therefore, the most important item in this discussion, and considerable space is devoted to it.

Table IV shows the value of food consumed per family and per person and the amount bought and furnished by the farm. The average value of the food used per family was $447.92, and $94 per person, 41.6 per cent of which was bought and 58.4 furnished by the farm. It is interesting to note that the percentage furnished by the farm varies in different sections from 35 per cent to 82 per cent. The California area was low with 35 per cent, but we find that individual families within this one area vary from 10 to 65 per cent, showing that some families could probably depend more on the farm for family table supplies, but also that the average for families with the highest per cent furnished is less than the average for all families in some other sections, and that apparently it is more profitable in this region to buy certain farm products than to raise them. Figure 2 shows graphically the average annual value of food used per family.

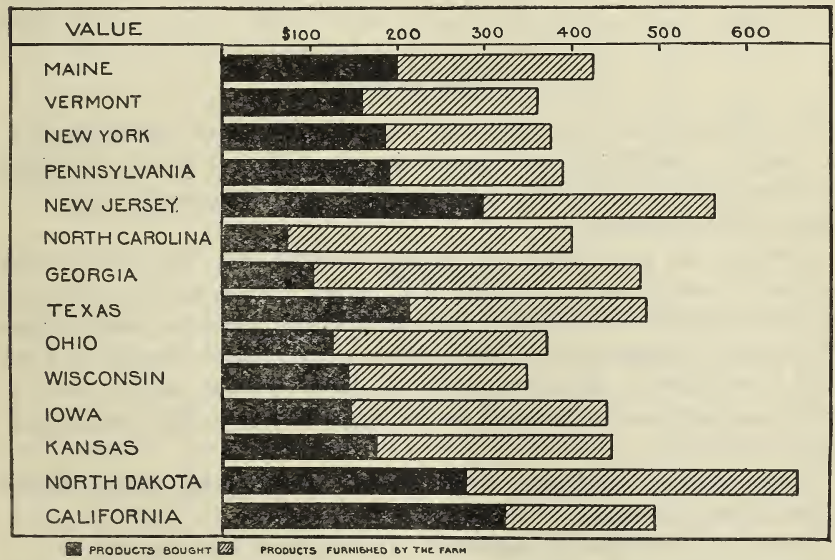

FIG. 2.—Average annual value of food used per family, showing relative amounts bought and furnished by the farm.

In arriving at the value of the food furnished by the farm average farm prices were taken. The farmer's estimate as to what the product would sell for on the farm when in season was checked with the local grocers' estimate, and in this manner fair average values were charged for the fruits, vegetables, and other farm products used in the house.

TABLE IV.—*Average annual value of the food of 950 farm families.*

County and State.	Number of families.	Food consumed per family.			Per cent of food consumed.		Total consumption per person.
		Bought.	Furnished by farm.	Total.	Bought.	Furnished by farm.	
Oxford, Me	148	$198.55	$224.87	$423.42	53.2	46.8	$94.88
Lamoille, Vt	49	169.17	192.43	361.60	46.8	53.2	75.34
Otsego, N. Y	55	186.71	189.60	376.31	49.6	50.4	94.08
Bucks, Pa	43	190.32	201.69	392.01	48.6	51.4	75.40
Gloucester N. J	126	297.41	264.94	562.35	52.9	47.1	120.26
Gaston, N. C	55	71.28	330.65	401.93	17.7	82.3	89.32
Troup, Ga	50	104.43	376.03	480.46	21.7	78.3	88.97
McLennan, Tex	44	213.47	275.62	489.09	43.6	56.4	92.30
Champaign, Ohio	44	124.98	248.28	373.26	33.5	66.5	91.07
Jefferson, Wis	51	143.25	209.44	352.69	40.6	59.4	80.16
Montgomery, Iowa	46	146.43	297.28	443.71	33.0	67.0	105.67
Cloud, Kans	46	157.41	292.48	449.89	35.0	65.0	99.97
Cass, N. Dak	109	279.28	384.95	664.23	42.0	58.0	107.03
Santa Clara, Cal	84	323.51	176.40	499.91	64.7	35.3	101.57
All families	950	186.16	261.76	447.92	41.6	58.4	94.00

CLASSES OF FOOD.

The different items of food used fall naturally into certain groups. In order to facilitate the discussion, the different articles of food have been divided into four classes, namely, groceries, animal products, fruits, and vegetables.

Groceries do not include all articles bought, but only those most generally bought, such as coffee, flour, sugar, bread, sirups, soda, etc. In this class are also included lemons, oranges, bananas, and raisins. The farmer naturally associates these with grocery items, and on most farms they really do not take the place of other fruits.

Animal products include all meats, eggs, butter, milk, cream, lard, cheese, and honey.

Fruits include all fruits, fresh, dried, and canned, except those listed under groceries.

Vegetables include all vegetables, fresh, dried, and canned.

Table V shows the relative importance of the different classes of foods for the different areas, animal products being easily the most important in value with 57.8 per cent of the total, followed by groceries with 24.8 per cent, vegetables 11 per cent, and fruits 6.4 per cent.

The last three classes may be termed the farm products group. They include those items of food which are distinctly farm products. They constitute approximately 75 per cent of the total value of the food consumed. Instead of 75 per cent of the food consumed being furnished by the farm, however, we find only 58 per cent of it is furnished (see Table IV), showing that nearly one-fourth of the farm products consumed by farm families are bought rather than taken from the home farm. It is not intended to imply by this statement that all should be raised. The most important articles bought in this group are meat and butter. The meat bill could, no doubt, be reduced with proper household management; but butter making on the farm can not wisely be encouraged when the milk and cream may be sold. Where only a few cows are kept for the family supply of milk and butter, butter making on the farm may not be out of place, for it is easier to market a few pounds of butter every week than a few quarts of milk every day.

TABLE V.—*Distribution of value of food used annually (950 families).*

County and State.	Per cent of total value of food in each class.			
	Groceries.	Animal products.	Fruit.	Vegetables.
Oxford, Me	25.9	56.9	7.2	10.0
Lamoille, Vt	31.0	52.7	5.8	10.5
Otsego, N. Y	27.7	55.5	6.0	10.8
Bucks, Pa	27.1	56.4	6.5	10.0
Gloucester, N. J	24.9	57.3	5.0	12.8
Gaston, N. C	21.0	55.0	8.7	15.3
Troup, Ga	21.1	56.6	5.1	17.2
McLennan, Tex	24.2	60.6	3.7	11.5
Champaign, Ohio	25.5	60.7	6.3	7.5
Jefferson, Wis	26.0	56.0	8.0	10.0
Montgomery, Iowa	22.0	61.0	6.0	11.0
Cloud, Kans	22.9	58.8	7.0	11.3
Cass, N. Dak	22.3	63.6	6.6	7.5
Santa Clara, Cal	25.2	58.6	7.9	8.3
Average, all families	24.8	57.8	6.4	11.0

GROCERIES.

This class of foods constitutes about 25 per cent of the total food used. The most important items of food in this group, in quantities consumed, are sugar and flour. The quantity of sugar and flour bought depends upon the individual tastes of the families. Those doing much canning naturally use the most sugar. In some sections bread is bought and thus less flour consumed. In some sections sugar is bought by the dollar or half dollar's worth, in others in 5 and 10 pound lots, and in still others it is common practice to buy in 25 or 100 pound bags. Trading is most generally done in small quantities. Occasionally a family will buy certain of its grocery items from mail-order houses.

The practice of trading farm products for groceries is becoming less prevalent. The common products used for trading are butter and eggs. Less butter is being made on the farm than heretofore, and eggs often find a better market than the grocery, so that it is a very common occurrence in many communities for farmers to pay cash for all their groceries.

In some communities it is still common practice with farmers to take corn and wheat to the mill to be ground into meal and flour for family use. In some southern sections this is still the usual procedure, and undoubtedly is to the financial advantage of the farmer. It seems, however, to be gradually losing favor.

It is interesting to note here the average distance the farmer has to go to buy his groceries. The average distance to town for the farmers visited in New Jersey was 1.9 miles; in Maine. 2.4 miles; in North Dakota, 4.5 miles; and in California. 3 miles

ANIMAL PRODUCTS.

This group of food items constitutes 57.8 per cent of the total value of food consumed by the families visited. In none of the sections visited does this group furnish less than 50 per cent of the total food used, and in the North Dakota area it amounted to 63.6 per cent of the total. There is a variation of less than 10 per cent in the different areas for this group, indicating that this class of food is the most nearly indispensable. It is interesting to note, however, that the percentage furnished by the farm for this group varies from 46.1 to 97.3 per cent, the average for all sections being 76.6, as is shown in Table VI. The farm unquestionably should furnish the major part of the food products for this group.

TABLE VI.—*Proportion of value of groceries, animal products, fruits, and vegetables bought and furnished by farm (950 families).*

Location of regions in which study was made (county and State).	Groceries.		Animal products.		Fruits.		Vegetables.	
	Bought.	Furnished by farm.	Bought.	Furnished by farm.	Bought.	Furnished by farm.	Bought.	Furnished by farm.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Oxford, Me	100.0	....	42.2	57.8	22.4	77.6	15.7	84.3
Lamoille, Vt	92.8	7.2	27.6	72.4	23.6	76.4	16.3	83.7
Otsego, N. Y	96.0	4.0	36.6	63.4	25.1	74.9	12.3	87.7
Bucks, Pa	97.8	2.2	33.2	66.8	25.2	74.8	15.4	84.6
Gloucester, N. J	100.0	....	44.6	55.4	35.4	64.6	5.3	94.7
Gaston, N. C	76.0	24.0	2.7	97.3	2.0	98.0	3.9	96.1
Troup, Ga	89.7	10.3	5.7	94.3	10.9	89.1	1.0	99.0
McLennan, Tex	98.7	1.3	14.2	85.8	98.9	1.1	66.1	33.9
Champaign, Ohio	97.0	3.0	8.4	91.6	38.2	61.8	16.2	83.8
Jefferson, Wis	98.7	1.3	21.2	78.8	26.8	73.2	6.3	93.7
Montgomery, Iowa	98.4	1.6	4.3	95.7	44.5	55.5	27.0	73.0
Cloud, Kans	99.2	.8	10.9	89.1	38.6	61.4	27.6	72.4
Cass, N. Dak	100.0	....	21.8	78.2	84.2	15.8	4.5	95.5
Santa Clara, Cal	96.1	3.9	53.9	46.1	38.2	61.8	70.9	29.1
Average, all families	95.7	4.3	23.4	76.6	36.7	63.3	20.6	79.4

In Table VII this group is divided into three divisions, namely, meat products, dairy products, and poultry products, giving the average value of the amount consumed annually per person and per family. The table shows that the dairy products used, which include cream, milk, butter, and cheese, run slightly less in value than the meat products, which include beef, pork, mutton, lard, and fish. The poultry products consumed amount to about one-half as much as either of the other two groups. Practically none of the poultry products is bought and only 14 per cent of the dairy products; but one-third of the meat consumed is bought.

Table VII.—*Average annual value of meat products, poultry products, and dairy products consumed (950 families).*

County and State.	Meat products.		Dairy products.		Poultry products.	
	Per person.	Per family.	Per person.	Per family.	Per person.	Per family.
Oxford, Me	$22.94	$103.23	$21.50	$96.75	$9.24	$41.58
Lamoille, Vt	11.88	57.02	21.18	101.66	6.39	30.67
Otsego, N. Y	18.38	73.52	20.18	80.72	13.33	53.32
Bucks, Pa	23.61	122.77	11.37	59.12	7.64	39.73
Gloucester, N. J	40.32	197.57	16.29	79.82	12.20	59.78
Gaston, N. C	14.85	66.82	25.30	113.85	8.37	37.66
Troup, Ga	17.27	93.26	23.28	125.71	9.44	50.98
McLennan, Tex	21.61	114.53	23.83	126.30	10.37	54.96
Champaign, Ohio	20.79	85.25	20.98	86.02	14.95	61.30
Jefferson, Wis	18.68	78.46	15.05	63.21	10.55	44.31
Montgomery, Iowa	21.87	96.23	24.13	106.17	17.56	77.26
Cloud, Kans	21.00	94.50	22.83	102.74	14.34	64.53
Cass, N. Dak	27.76	172.11	24.75	153.45	15.53	96.29
Santa Clara, Cal	29.83	146.17	16.63	81.49	12.90	63.21
Average, all families	22.20	107.25	20.52	98.36	11.63	55.40

MEAT.

Table VIII shows the relative value of beef, pork, and poultry furnished by the farm and the proportion of all meats bought and furnished by the farm. It will be noted that of the meat furnished by the farm, pork is easily the most important, constituting 60.8 per cent of the total, poultry being next with 29.2 per cent, and beef being 10 per cent. The relative quantity of pork used is highest in

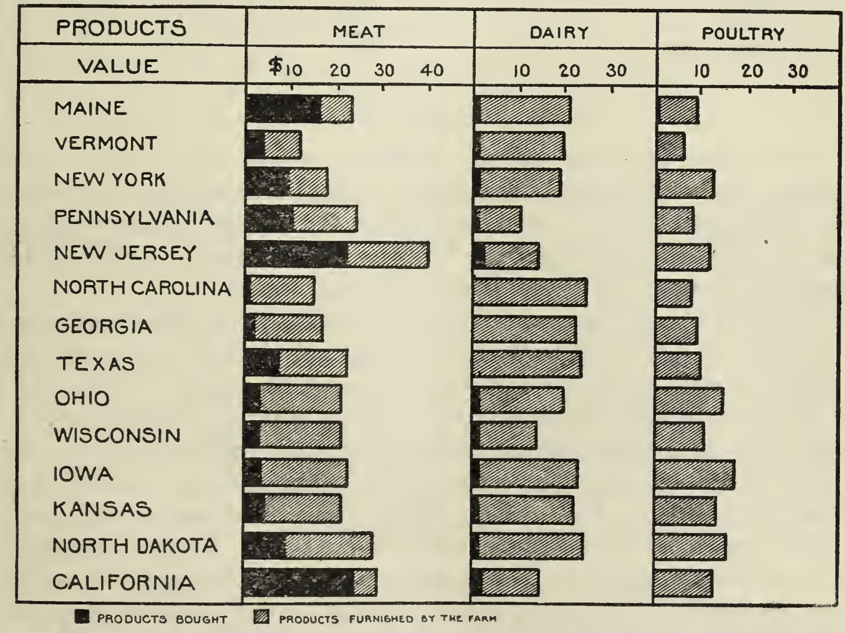

Fig. 3.—Value of average annual consumption per person of meat products, dairy products, and poultry products, showing relative amounts bought and furnished by the farm.

the South and lowest in the North. The farmers in the South also get more of their meat directly from the farm than those of the North. Poultry is included in Table VIII as a meat, but in Table VII it is included under poultry products. Of the meat that is bought, two-thirds is beef and the rest is pork and fish.

TABLE VIII.—*Relative value of different kinds of meats furnished by farm and proportion of meats furnished by farm and bought (950 families).*

Location of regions in which study was made (county and State).	Per cent of value of meats furnished by farm.			Per cent of value of all meats.	
	Pork.	Beef.	Poultry.	Bought.	Furnished by farm.
Oxford, Me	50.6	11.1	38.3	35.1	64.9
Lamoille, Vt	51.9	21.1	27.0	33.8	66.2
Otsego, N. Y	47.5	17.9	34.6	43.6	56.4
Bucks, Pa	63.9	18.8	17.3	40.2	59.8
Gloucester, N. J	69.4	5.0	25.6	41.2	58.8
Gaston, N. C	81.4	1.2	17.4	6.3	93.7
Troup, Ga	71.9	5.4	22.7	9.2	90.8
McLennan, Tex	75.6	....	24.4	24.6	75.4
Champaign, Ohio	69.1	5.4	25.5	13.7	86.3
Jefferson, Wis	70.0	8.7	21.3	20.9	79.1
Montgomery, Iowa	59.4	11.4	29.2	15.7	84.3
Cloud, Kans	50.8	17.1	32.1	15.1	84.9
Case, N. Dak	56.6	13.3	30.1	37.1	62.9
Santa Clara, Cal	33.9	3.1	63.0	24.0	76.0
Average, all farms	60.8	10.0	29.2	25.8	74.2

DAIRY PRODUCTS.

The dairy products group, including cream, milk, butter, and cheese, amounts to $98 as an average annual consumption per family for all families visited. As stated before, 14 per cent of these products are bought and 86 per cent are furnished by the farm. Considerable butter is bought, but very little milk and cream.

Table IX shows the quantity of dairy products consumed, expressed in terms of quarts of milk. It is assumed that on the average 8 quarts of milk make 1 quart of cream and 10 quarts of milk make 1 pound of butter. Reducing the items to quarts of milk, it will be seen that the average annual consumption per person for all families visited is 550 quarts. The consumption per person varied in different areas from 434 to 746 quarts. More cream and butter were used in those areas where butter was made on the farm. The farm supplied 473 of the 550 quarts. The average number of persons per family for the families visited is 4.8, making the average number of quarts of milk furnished by the farm for home consumption 2,270 per year. In the southern areas it is assumed that the milk churned for home consumption of butter will furnish enough buttermilk for the family, and thus the equivalent of milk for the butter will cover that for buttermilk.

TABLE IX.—*Dairy products consumed per person in equivalent quarts of whole milk (950 families).*

[Data assume 8 quarts of milk make 1 quart of cream and 10 quarts of milk make 1 pound of butter.]

County and State.	Cream.	Milk.	Butter.	Total consumed.	Total bought.	Total furnished by farm.
Oxford, Me	123	126	299	548	142	406
Lamoille, Vt	178	188	294	660	153	507
Otsego, N. Y	11	204	377	592	241	351
Bucks, Pa	....	130	201	331	97	234
Gloucester, N. J	5	184	245	434	92	342
Gaston, N. C	....	133	406	539	4	535
Troup, Ga	....	30	520	550	....	550
McLennan, Tex	....	43	442	485	1	484
Champaign, Ohio	72	258	298	628	21	607
Jefferson, Wis	....	152	310	462	132	330
Montgomery, Iowa	17	252	370	639	7	632
Cloud, Kans	40	251	350	641	21	620
Cass, N. Dak	136	212	398	746	39	707
Santa Clara, Cal	....	210	228	438	119	319
Average, all farms	42	170	338	550	77	473

FRUITS.

The value of fruit consumed constitutes 6.4 per cent of the total. Sixty-three per cent of this is furnished by the farm. Fruits include a class of food products which can be raised much more cheaply than bought. In the North Dakota area, for instance, only one-sixth of the fruit used is raised on the farm, and yet the value of the fruit consumed in this area is relatively as great as in the other sections, owing to the higher price paid per unit quantity of fruit.

VEGETABLES.

Table V shows that 11 per cent of the value of the food consumed represents vegetables, 79.4 per cent of which are furnished by the farm. That the farmer can easily raise most of his vegetables is shown by the fact that he raises a greater proportion of this group than of any other group. In raising his own vegetables he eliminates the cost of transportation and the commission of the middleman, which are included in the prices he pays for purchased vegetables. In five of the areas visited over 90 per cent of the vegetables used are supplied by the farm, in the Georgia area only 1 per cent being bought. In some sections certain vegetables will not thrive, owing to peculiar soil or climatic conditions. This accounts for some of the vegetables bought.

EFFECT OF DIFFERENT DIETARY SYSTEMS ON FOOD COST.

There is a considerable variation in the cost of food for families of the same size. This difference may be due either to the fact that the members of the family are larger consumers or that they consume more of the higher-priced foods. In this connection, it is interesting to note the effect that the high or low consumption of one class of food products has on the quantity of other food consumed and on the total consumption and also on the relative value of food bought and furnished by the farm.

In Table X the families have been divided according to the relative value of meat consumed. In both areas studied the relative value of groceries, fruits, vegetables, and dairy products decreases as the value of meat increases. The value of the total consumption of food increases with the increase of the consumption of meat, the size of family remaining nearly constant. The high meat-consuming families also buy much more of their food, which is due to the fact that they buy much more of their meat and use less groceries, which class includes the non-farm-furnished foods.

TABLE X.—*Relation of the relative quantity of meat consumed to that of other classes of food and the total consumption of food.*

NEW JERSEY.

Meat, per cent of total.	Number of families.	Average size family.	Average percentage of total consumption.								Total consumption per person.
			Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	
25 and less....	31	4.4	28.5	6.7	15.1	20.7	12.8	16.2	53	47	$99.63
26 to 35........	54	4.7	25.7	5.2	13.1	31.0	10.4	14.5	48	52	127.30
36 and over...	41	4.9	21.9	4.1	11.0	43.6	8.5	10.8	42	58	125.30

MAINE.

Meat, per cent of total.	Number of families.	Average size family.	Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	Total consumption per person.
20 and less....	60	4.6	27.7	8.5	11.2	16.9	10.7	25.0	52	48	$86.39
21 to 29........	59	4.5	25.9	7.1	9.5	24.8	9.4	23.3	46	54	97.42
30 and over...	29	4.0	23.1	5.1	8.5	36.5	8.7	18.1	37	63	108.97

The families have been divided into three classes, according to the value of vegetables consumed, as shown in Table XI. The value of meat and dairy products tends to decrease as the value of vegetables consumed increases, indicating that vegetables tend to replace some meat and dairy products in the farmer's diet. The value of the total consumption and the relative value of food bought decrease as the value of vegetables used increases.

TABLE XI.—*Relation of the relative quantity of vegetables consumed to that of other classes of food and the total consumption of food.*

NEW JERSEY.

Vegetables, per cent of total.	Number of families.	Average size family.	Average percentage of total consumption.								Total consumption per person.
			Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	
10 and less....	42	4.6	23.9	4.9	8.9	37.0	11.3	13.9	42	58	$133.87
11 to 13........	36	4.5	26.1	4.6	12.3	34.1	9.3	13.6	48	52	118.73
14 and over...	48	4.9	25.0	5.7	17.0	29.5	9.6	13.1	48	52	109.97

MAINE.

Vegetables, per cent of total.	Number of families.	Average size family.	Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	Total consumption per person.
8 and less.....	62	4.0	25.6	6.6	7.4	26.2	10.3	23.7	44	56	$104.36
9 to 10.........	37	4.7	25.5	6.6	9.7	25.2	9.7	23.2	46	54	94.24
10 and over...	49	4.8	26.7	8.6	13.3	20.7	9.1	21.4	51	49	85.38

In Table XII the division has been made by the value of dairy products consumed. Increase in dairy products used is accompanied by an appreciable decrease in the use of meat products, but no consistent variation in the other classes of foods. Dairy products are distinctly farm products, and the relative value of food furnished by the farm increases with the increase in value of dairy products used. There is no consistent variation in the value of total consumption of food.

TABLE XII.—*Relation of the relative quantity of dairy products consumed to that of other classes of food and the total consumption of food.*

NEW JERSEY.

Dairy products, per cent of total.	Number of families.	Average size family.	Average percentage of total consumption.								Total consumption per person.
			Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	
10 and less....	41	4.6	25.1	4.9	12.7	38.5	10.2	8.6	41	59	$123.54
11 to 15........	51	4.6	24.4	5.1	13.1	34.1	10.0	13.2	49	51	117.74
16 and over...	33	4.9	25.4	5.2	12.5	26.6	10.2	20.1	52	48	118.85
MAINE.											
19 and less....	53	4.4	27.0	7.6	10.7	27.6	10.5	16.2	45	55	$98.19
20 to 25........	50	4.5	26.3	6.6	10.0	24.2	10.2	22.4	47	53	92.56
26 and over...	45	4.6	24.3	7.3	9.0	20.0	8.3	30.9	49	51	93.64

An increase in the proportion of groceries used is accompanied by a decrease in the proportion of meat and poultry products. (Table XIII.) The less expensive grocery items seem to replace a large proportion of the more expensive meats. The value of the total consumption here again varies inversely with the relative proportion of groceries used.

Meats constituting such a large proportion of the total food value, their variation necessarily affects the total value of food consumed more than that of any other group. Only about one-third of the meat (not including poultry) used in these two areas is furnished by the farm, so that the variation in meat used also very appreciably affects the relative value of total food bought and furnished by the farm. The data indicate that the expenditure for meats and the value of the total consumption of food may be materially reduced by the increase in the use of vegetables, poultry products, and dairy products, the groups of foods which are largely furnished directly by the farm.

TABLE XIII.—*Relation of the relative quantity of groceries consumed to that of other classes of food and the total consumption of food.*

NEW JERSEY.

Groceries, per cent of total.	Number of families.	Average size family.	Average percentage of total consumption.								Total consumption per person.
			Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	
20 and less....	32	4.7	17.9	4.8	12.5	40.9	11.2	12.7	49	51	$133.44
21 to 28.......	55	4.8	24.9	5.2	13.2	32.5	9.7	14.5	49	51	122.60
29 and over...	39	4.5	32.5	5.2	12.3	27.2	9.8	13.0	42	58	105.59

MAINE.

Groceries, per cent of total.	Number of families.	Average size family.	Groceries.	Fruits.	Vegetables.	Meat products.	Poultry products.	Dairy products.	Furnished by farm.	Bought.	Total consumption per person.
24 and less....	56	4.2	20.9	7.3	9.4	25.8	11.2	25.1	50	50	$110.84
25 to 30.......	59	4.8	27.3	7.4	10.2	24.4	9.2	21.3	47	53	89.56
31 and over...	33	4.2	34.1	6.6	10.4	19.9	7.7	21.1	40	60	80.84

SIZE OF FAMILY AND FOOD PER PERSON.

The number of persons in the family bears a direct relation to the value of food consumed per person. Table XIV shows that this variation is not limited to the total consumption, but applies also to the quantity bought and that furnished by the farm. The families were divided into three groups, the first group consisting of families of 2 and 3 persons, the second of families of 4 and 5 persons, and the third of families of 6 persons and more. The value of total consumption per person for the first group averages $114; for the second group, $96; and for the third, $84. The values of supplies bought per person for those groups in the same order average $49, $40, and $35, and the values of food furnished by farm are $65, $56, and $49, respectively. The relative value bought and furnished, however, does not vary in the different groups; that is, the percentage of the total consumption bought and furnished by the farm is about the same for large families as for small families. The value of the consumption of the different classes of food is also relatively the same, indicating that there is more economical utilization of food products in large families than in small families.

TABLE XIV.—*Relation of size of family to annual cost of food (950 families).*

Location of regions in which study was made (county and State).	Families of 2 or 3 persons.				Families of 4 or 5 persons.				Families of 6 persons or over.			
	Number of families.	Average per person.			Number of families.	Average per person.			Number of families.	Average per person.		
		Bought.	Furnished by farm.	Total.		Bought.	Furnished by farm.	Total.		Bought.	Furnished by farm.	Total.
Oxford, Me.	55	$60	$52	$112	65	$49	$43	$92	28	$46	$41	$87
Lamoille, Vt.	18	40	54	94	15	38	40	78	16	31	32	63
Otsego, N. Y.	25	53	53	106	22	44	47	91	8	43	41	84
Bucks, Pa.	9	44	48	92	22	39	45	84	12	32	30	62
Gloucester, N. J.	43	79	62	141	54	63	62	125	29	55	47	102
Gaston, N. C.	23	23	83	107	13	16	78	94	19	12	69	81
Troup, Ga.	9	24	95	119	18	23	76	99	23	17	62	79
McLennan, Tex.	11	55	78	133	16	40	56	96	17	37	43	80
Champaign, Ohio	22	39	69	108	16	28	59	87	6	24	53	77
Jefferson, Wis.	22	45	53	98	20	27	49	76	9	34	40	74
Montgomery, Iowa	19	38	82	120	19	33	62	95	8	33	70	103
Cloud, Kans.	19	39	68	107	16	35	65	100	11	32	62	94
Cass, N. Dak.	16	58	78	136	40	53	69	122	53	40	57	97
Santa Clara, Cal.	31	89	38	127	28	70	39	109	25	52	33	85
All families.	322	49	65	114	364	40	56	96	264	35	49	84

CONSUMPTION OF INDIVIDUAL FOOD ITEMS.

Table XV gives the average annual consumption per person and per family, with the quantity furnished by the farm and quantity bought, of practically all food items used by the families. It presents the details on which the generalized data in the other tables are based. In the other tables quantities are represented by values, because the difference in the common units for the various items makes value the only common basis of comparison. Table XV, however, gives the quantities in units which represent exactly the same volume in all sections, making the data comparable one section with another. If the reader is interested in the consumption of any particular article, or group of articles, this table will give him the desired information.

TABLE XV.—*Average quantity per family and per person of the various articles of food consumed, the average quantity furnished by the farm, and the quantity bought per family (950 families).*

GROCERIES.

State.	Coffee (pounds).				Cocoa (pounds).				Tea (pounds).			
	Per family.			Per person.	Per family.			Per person.	Per family.			Per person.
	Furnished.	Bought.	Total.		Furnished.	Bought.	Total.		Furnished.	Bought.	Total.	
Vt.		15.3	15.3	3.2		6.2	6.2	1.3		13.3	13.3	2.7
Me.		21.4	21.4	4.8		5.4	5.4	1.2		9.8	9.8	2.2
N. Y.		24.8	24.8	6.2		6.4	6.4	1.6		8.0	8.0	2.0
Pa.		38.0	38.0	7.3		8.3	8.3	1.6		1.6	1.6	.3
N. J.		55.1	55.1	11.7		6.1	6.1	1.3		10.8	10.8	2.3
N. C.		31.9	31.9	7.1		.9	.9	.2				
Ga.		31.5	31.5	5.8		1.1	1.1	.2		1.6	1.6	.3
Tex.		53.5	53.5	10.1		3.2	3.2	.6		2.7	2.7	.5
Ohio		38.9	38.9	9.5		4.1	4.1	1.0		3.3	3.3	.8
Wis.		44.0	44.0	10.0		6.2	6.2	1.4		2.2	2.2	.5
Iowa		45.7	45.7	10.8		3.4	3.4	.8		4.2	4.2	1.0
Kans.		39.2	39.2	8.7		4.0	4.0	.9		4.5	4.5	1.0
N. Dak.		58.9	58.9	9.5		6.2	6.2	1.0		14.9	14.9	2.4
Cal.		41.6	41.6	8.5		6.4	6.4	1.3		8.3	8.3	1.7
	Sugar (pounds).				Salt (pounds).				Flour (pounds).			
Vt.		372.0	372.0	76.8		58.1	58.1	12.0		1,132.0	1,132.0	230.0
Me.		437.0	437.0	97.9		68.2	68.2	15.3		932.0	932.0	209.0
N. Y.		376.0	376.0	94.0		64.0	64.0	16.0		736.0	736.0	184.0
Pa.		359.0	359.0	69.0		86.3	86.3	16.6	36.7	696.3	733.0	141.0
N. J.		556.0	556.0	118.0		127.2	127.2	27.0		690.0	690.0	146.5
N. C.		279.0	279.0	62.0		13.5	13.5	3.0	408.3	999.7	1,408.0	313.0
Ga.		313.0	313.0	57.6		27.1	27.1	5.0		1,260.0	1,260.0	232.0
Tex.		325.0	325.0	61.3		27.0	27.0	5.1		1,092.0	1,092.0	206.0
Ohio		377.0	377.0	92.0		20.5	20.5	5.0	7.5	746.5	754.0	184.0
Wis.		321.0	321.0	73.0		13.2	13.2	3.0		1,012.0	1,012.0	230.0
Iowa		408.0	408.0	96.5		15.2	15.2	3.6	580.8	299.2	880.0	208.0
Kans.		369.0	369.0	82.0		16.6	16.6	3.7	29.8	964.2	994.0	221.0
N. Dak.		529.0	529.0	85.3		111.6	111.6	18.0		1,318.0	1,318.0	212.5
Cal.		324.0	324.0	66.2		83.3	83.3	17.0		382.0	382.0	180.0
	Cornmeal (pounds).				Bread bought (pounds).				Oatmeal (pounds).			
Vt.		69.7	69.7	14.4		87.6	87.6	18.1		65.8	65.8	13.6
Me.		62.4	62.4	14.0		67.8	67.8	15.2		45.9	45.9	10.3
N. Y.		26.8	26.8	6.7		176.8	176.8	44.2		35.6	35.6	8.9
Pa.	26.1	29.5	55.6	10.7		556.4	556.4	107.0		21.8	21.8	4.2
N. J.		18.8	18.8	4.0		570.0	570.0	121.0		33.0	33.0	7.0
N. C.	330.9	53.9	384.8	85.8		4.5	4.5	1.0		7.6	7.6	1.7
Ga.	488.6	240.6	729.2	134.3		18.5	18.5	3.4		17.4	17.4	3.2
Tex.	94.1	298.1	392.2	74.0		48.8	48.8	9.2		35.0	35.0	6.6
Ohio	57.7	28.4	86.1	21.0		162.4	162.4	39.6		51.2	51.2	12.5
Wis.		17.6	17.6	4.0		74.8	74.8	17.0		37.4	37.4	8.5
Iowa	3.3	33.1	36.4	8.6		84.6	84.6	20.0		292.7	292.7	69.2
Kans.		102.6	102.6	22.8		144.0	144.0	32.0		48.6	48.6	10.8
N. Dak.		41.5	41.5	6.7		21.1	21.1	3.4		66.3	66.3	10.7
Cal.		36.3	36.3	7.4		197.0	197.0	40.2		68.6	68.6	14.0

TABLE XV.—*Average quantity per family and per person of the various articles of food consumed, the average quantity furnished by the farm, and the quantity bought per family (950 families)*—Continued.

GROCERIES—Continued.

State.	Other cereals (pounds).				Graham flour (pounds).				Rice (pounds).			
	Per family.			Per person.	Per family.			Per person.	Per family.			Per person.
	Furnished.	Bought.	Total.		Furnished.	Bought.	Total.		Furnished.	Bought.	Total.	
Vt	......	9.7	9.7	2.0	......	32.4	32.4	6.7	......	14.0	14.0	2.9
Me	......	18.3	18.3	4.1	......	18.7	18.7	4.2	......	12.9	12.9	2.9
N. Y	......	12.0	12.0	3.0	......	4.0	4.0	1.0	......	12.0	12.0	3.0
Pa	......	10.4	10.4	2.0	......	......	......	......	......	17.7	17.7	3.4
N. J	......	14.1	14.1	3.0	......	......	......	......	......	28.7	28.7	6.1
N. C	......	2.7	2.7	.6	......	......	......	......	......	22.5	22.5	5.0
Ga	......	5.4	5.4	1.0	......	......	......	......	......	29.3	29.3	5.4
Tex	......	3.7	3.7	.7	......	......	......	......	......	35.0	35.0	6.6
Ohio	......	17.2	17.2	4.2	......	......	......	......	......	26.2	26.2	6.4
Wis	......	12.3	12.3	2.8	......	.9	.9	.2	......	14.5	14.5	3.3
Iowa	......	97.3	97.3	23.0	......	......	......	......	......	19.5	19.5	4.6
Kans	......	16.2	16.2	3.6	......	......	......	......	......	23.4	23.4	5.2
N. Dak	......	26.7	26.7	4.3	......	27.9	27.9	4.5	......	22.3	22.3	3.6
Cal	......	27.4	27.4	5.6	......	28.4	28.4	5.8	......	48.5	48.5	9.9

State.	Currants (pounds).				Sirups (gallons).				Lemons (dozens).			
	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.
Vt	......	29.0	29.0	6.0	12.2	4.3	16.5	3.4	......	3.6	3.6	0.8
Me	......	21.4	21.4	4.8	......	13.8	13.8	3.1	......	4.5	4.5	1.0
N. Y	......	28.8	28.8	7.2	4.5	5.5	10.0	2.5	......	4.4	4.4	1.1
Pa	......	27.0	27.0	5.2	......	9.4	9.4	1.8	......	5.2	5.2	1.0
N. J	......	22.6	22.6	4.8	......	6.6	6.6	1.4	......	13.2	13.2	2.8
N. C	......	5.0	5.0	1.1	3.6	4.5	8.1	1.8	......	1.4	1.4	.3
Ga	......	2.7	2.7	.5	11.7	8.4	20.1	3.7	......	2.2	2.2	.4
Tex	......	42.4	42.4	8.0	......	18.6	18.6	3.5	......	4.2	4.2	.8
Ohio	......	22.6	22.6	5.5	......	3.7	3.7	.9	......	4.1	4.1	1.0
Wis	......	25.5	25.5	5.8	2.1	4.5	6.6	1.5	......	3.1	3.1	.7
Iowa	......	36.8	36.8	8.7	......	5.5	5.5	1.3	......	5.1	5.1	1.2
Kans	......	21.2	21.2	4.7	......	5.4	5.4	1.2	......	5.8	5.8	1.3
N. Dak	......	23.6	23.6	3.8	......	9.3	9.3	1.5	......	9.3	9.3	1.5
Cal	......	14.7	14.7	3.0	......	3.9	3.9	.8	3.5	8.7	12.2	2.5

State.	Oranges (dozens).				Bananas (dozens).				Buckwheat (pounds).			
	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.
Vt	......	4.8	4.8	1.0	......	15.5	15.5	3.2	18.0	13.5	31.5	6.5
Me	......	10.3	10.3	2.3	......	18.3	18.3	4.1				......
N. Y	......	7.2	7.2	1.8	......	18.4	18.4	4.6	84.3	51.7	136.0	34.0
Pa	......	7.8	7.8	1.5	......	10.9	10.9	2.1	......	20.8	20.8	4.0
N. J	......	16.5	16.5	3.5	......	20.7	20.7	4.4	......	......	......	......
N. C	......	1.8	1.8	.4	......	3.6	3.6	.8	......	......	......	......
Ga	......	2.7	2.7	.5	......	4.9	4.9	.9	......	......	......	......
Tex	......	5.3	5.3	1.0	......	11.1	11.1	2.1	......	......	......	......
Ohio	......	5.3	5.3	1.3	......	11.1	11.1	2.7	......	......	......	......
Wis	......	4.4	4.4	1.0	......	8.4	8.4	1.9	......	8.8	8.8	2.0
Iowa	......	6.3	6.3	1.5	......	12.7	12.7	3.0	......	......	......	......
Kans	......	7.2	7.2	1.6	......	14.8	14.8	3.3	......	2.2	2.2	.5
N. Dak	......	12.4	12.4	2.0	......	11.2	11.2	1.8	......	......	......	......
Cal	4.1	16.5	20.6	4.5	......	8.3	8.3	1.7	......	......	......	......

TABLE XV.—*Average quantity per family and per person of the various articles of food consumed, the average quantity furnished by the farm, and the quantity bought per family (950 families)*—Continued.

ANIMAL PRODUCTS.

State.	Pork (pounds).				Beef (pounds).				Poultry (pounds).			
	Per family.				Per family.				Per family.			
	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.
Vt.	251.2	66.8	318.0	65.6	102.5	65.5	168.0	34.6	87.0	....	87.0	18.0
Me.	169.5	56.5	226.0	50.6	226.2	36.8	263.0	59.0	94.0	1.0	95.0	21.4
N. Y.	192.7	99.3	292.0	73.0	95.9	150.1	246.0	61.5	166.3	1.7	168.0	41.9
Pa.	48.8	86.2	575.0	110.5	120.3	255.7	376.0	72.3	117.0	....	117.0	22.5
N. J.	538.2	151.8	690.0	146.4	35.4	406.6	442.0	93.9	146.0	....	146.0	31.0
N. C.	545.5	5.5	551.0	122.4	9.0	32.0	41.0	9.1	233.0	....	233.0	51.7
Ga.	695.0	7.0	702.0	129.3	70.2	64.8	135.0	24.8	382.0	....	382.0	70.4
Tex.	628.1	137.9	766.0	144.5	....	76.0	76.0	14.3	276.0	....	276.0	52.0
Ohio.	663.6	42.4	706.0	172.2	57.5	57.5	115.0	28.1	301.0	....	301.0	73.5
Wis.	590.4	65.6	656.0	149.0	70.1	75.9	146.0	33.1	176.0	....	176.0	40.0
Iowa.	659.5	13.5	673.0	159.0	118.8	114.2	233.0	55.1	296.0	....	296.0	70.0
Kans.	546.8	41.2	588.0	130.6	148.8	80.2	229.0	50.8	477.0	....	477.0	106.0
N. Dak.	889.6	77.4	967.0	156.0	283.4	152.6	436.0	70.4	226.0	....	226.0	36.4
Cal.	131.8	84.2	216.0	44.1	14.1	454.9	469.0	95.7	187.1	1.9	189.0	38.5

	Fish (pounds).				Milk (quarts).				Butter (pounds).			
Vt.	....	38.0	38.0	7.8	911.0	....	911.0	188.2	68.2	73.8	142.0	29.4
Me.	3.6	115.4	119.0	26.6	557.4	5.6	563.0	126.2	75.8	57.2	133.0	29.9
N. Y.	....	23.0	23.0	5.7	815.0	....	815.0	203.7	54.4	96.6	151.0	37.7
Pa.	....	57.0	57.0	11.0	669.2	6.8	676.0	130.0	60.3	43.7	104.0	20.1
N. J.	....	119.0	119.0	25.2	798.6	69.4	868.0	184.4	79.4	35.6	115.0	24.5
N. C.	....	3.0	3.0	.7	600.0	....	600.0	133.4	181.2	1.8	183.0	40.6
Ga.	....	6.0	6.0	1.2	164.0	....	164.0	30.2	282.0	....	282.0	52.0
Tex.	....	13.0	13.0	2.5	224.6	4.6	229.0	43.2	234.0	....	234.0	44.2
Ohio.	....	2.0	2.0	.5	1,057.0	....	1,057.0	257.7	113.5	8.5	122.0	29.8
Wis.	....	3.0	3.0	.7	633.7	33.3	667.0	152.0	81.6	54.4	136.0	31.0
Iowa.	....	6.0	6.0	1.3	1,066.0	....	1,066.0	252.0	152.9	3.1	156.0	37.0
Kans.	....	5.0	5.0	1.1	1,130.0	....	1,130.0	251.2	148.5	9.5	158.0	35.0
N. Dak.	....	47.0	47.0	7.6	1,297.9	13.1	1,311.0	211.5	224.8	22.2	247.0	39.8
Cal.	....	151.0	151.0	30.8	852.4	174.6	1,027.9	209.5	71.7	40.3	112.0	22.8

	Eggs (dozens).				Cream (quarts).				Lard bought (pounds).			
Vt.	82.0	....	82.0	16.9	108.0	....	108.0	22.3	....	34.8	34.8	7.2
Me.	108.6	3.4	112.0	25.1	69.0	....	69.0	15.4	....	81.6	81.6	18.3
N. Y.	115.9	6.1	122.0	30.5	6.0	....	6.0	1.4	....	10.8	10.8	2.7
Pa.	94.0	....	94.0	18.0	....	....	....	....	....	20.3	20.3	3.9
N. J.	153.0	....	153.0	32.5	2.6	.4	3.0	.6	....	33.4	33.4	7.1
N. C.	122.0	....	122.0	27.0	....	....	....	....	....	2.2	2.2	.5
Ga.	144.0	....	144.0	26.6	....	....	....	....	....	5.4	5.4	1.0
Tex.	206.0	....	206.0	38.8	....	....	....	....	....	38.2	38.2	7.2
Ohio.	169.0	....	169.0	41.3	37.0	....	37.0	9.0	....	....	....	....
Wis.	163.7	3.3	167.0	37.8	....	....	....	....	....	3.5	3.5	.8
Iowa.	246.0	....	246.0	58.2	9.0	....	9.0	2.1	....	3.0	3.0	.7
Kans.	194.0	....	194.0	43.2	22.0	....	22.0	5.0	....	27.9	27.9	6.2
N. Dak.	284.0	....	284.0	45.8	104.0	1.0	105.0	17.0	....	24.8	24.8	4.0
Cal.	101.0	1.0	102.0	20.8	....	....	....	....	....	48.0	48.0	9.8

TABLE XV.—*Average quantity per family and per person of the various articles of food consumed, the average quantity furnished by the farm, and the quantity bought per family (950 families)*—Continued.

ANIMAL PRODUCTS—Continued.

State.	Buttermilk (quarts).				Honey (pounds).				Cheese (pounds).			
	Per family.			Per person.	Per family.			Per person.	Per family.			Per person.
	Furnished.	Bought.	Total.		Furnished.	Bought.	Total.		Furnished.	Bought.	Total.	
Vt	....	....	....	....	....	1.0	1.0	0.2	....	8.7	8.7	1.8
Me	....	....	....	....	1.9	2.1	4.0	.9	0.4	17.9	18.3	4.1
N. Y	....	....	....	....	2.4	8.4	10.8	2.7	2.3	14.5	16.8	4.2
Pa	....	....	....	....	1.1	1.0	2.1	.4	5.3	7.2	12.5	2.4
N. J	....	....	....	....	1.2	.2	1.4	.3	5.8	30.5	36.3	7.7
N. C	1,581.3	....	1,581.3	351.4	6.7	.9	7.6	1.7	....	.9	.9	.2
Ga	2,280.6	....	2,280.6	420.0	4.9	.5	5.4	1.0	2.2	7.6	9.8	1.8
Tex	2,090.3	....	2,090.3	394.4	8.0	6.8	14.8	2.8	....	5.3	5.3	1.0
Ohio	....	....	....	....	1.2	2.1	3.3	.8	2.1	6.9	9.0	2.2
Wis	....	....	....	....	2.6	6.2	8.8	2.0	....	20.2	20.2	4.6
Iowa	....	....	....	....	1.6	.9	2.5	.6	....	10.6	10.6	2.5
Kans	....	....	....	....	7:7	1.3	9.0	2.0	9.4	1.8	11.2	2.5
N. Dak	....	....	....	....	....	19.8	19.8	3.2	5.1	20.3	25.4	4.1
Cal	....	....	....	....	1.1	2.3	3.4	.7	4.5	29.8	34.3	7.0

FRUITS.

State.	Apples (bushels).				Peaches (pounds).				Plums (pounds).			
Vt	12.9	2.6	15.5	3.2	....	20.8	20.8	4.3	0.5	8.7	9.2	1.9
Me	17.1	.3	17.4	3.9	2.3	11.1	13.4	3.0	23.3	11.0	34.3	7.7
N. Y	18.8	....	18.8	4.7	....	60.0	60.0	15.0	....	1.6	1.6	.4
Pa	9.5	3.0	12.5	2.4	17.3	51.9	69.2	13.3	17.6	1.1	18.7	3.6
N. J	9.8	2.0	11.8	2.5	134.2	101.3	235.5	50.0	12.3	12.2	24.5	5.2
N. C	14.8	1.0	15.8	3.5	458.9	4.6	463.5	103.0	....	....	....	....
Ga	5.0	1.0	6.0	1.1	690.6	44.1	734.7	135.3	16.3	....	16.3	3.0
Tex	....	4.2	4.2	.8	....	174.9	174.9	33.0	....	....	....	....
Ohio	6.9	3.8	10.7	2.6	70.9	71.0	141.9	34.6	13.1	3.3	16.4	4.0
Wis	10.1	3.5	13.6	3.1	....	35.2	35.2	8.0	....	6.2	6.2	1.4
Iowa	16.6	4.1	20.7	4.9	.2	5.3	5.5	1.3	59.1	3.1	62.2	14.7
Kans	14.3	7.3	21.6	4.8	191.7	127.8	319.5	71.0	....	....	....	....
N. Dak	.4	7.0	7.4	1.2	....	198.4	198.4	32.0	54.2	48.1	102.3	16.5
Cal	.7	.3	1.0	.2	25.4	10.9	36.3	7.4	19.1	....	19.1	3.9

	Pears (pounds).				Berries (quarts).				Cherries (quarts).			
Vt	1.0	11.6	12.6	2.6	10.2	23.7	33.9	7.0	....	....	....	....
Me	69.9	23.3	93.2	20.9	77.5	17.0	94.5	21.2	27.6	4.5	32.1	7.2
N. Y	4.4	2.0	6.4	1.6	26.9	12.7	39.6	9.9	....	3.2	3.2	.8
Pa	160.1	8.4	168.5	32.4	43.0	3.8	46.8	9.0	30.2	4.1	34.3	6.6
N. J	68.1	2.1	70.2	14.9	54.7	23.5	78.2	16.6	47.1	5.2	52.3	11.1
N. C	135.0	....	135.0	30.0	156.6	....	156.6	34.8	....	....	....	....
Ga	54.3	....	54.3	10.0	19.0	8.2	27.2	5.0	....	....	....	....
Tex	....	30.7	30.7	5.8	....	34.4	34.4	6.5	....	....	....	....
Ohio	51.7	5.7	57.4	14.0	26.6	10.3	36.9	9.0	34.0	7.0	41.0	10.0
Wis	3.0	10.2	13.2	3.0	72.9	6.3	79.2	18.0	25.7	2.5	28.2	6.4
Iowa	4.9	12.0	16.9	4.0	15.4	8.3	23.7	5.6	66.1	11.7	77.8	18.4
Kans	14.6	25.9	40.5	9.0	13.9	6.8	20.7	4.6	45.0	4.5	49.5	11.0
N. Dak	....	107.9	107.9	17.4	18.0	24.8	42.8	6.9	5.8	6.6	12.4	2.0
Cal	12.8	1.9	14.7	3.0	9.4	26.9	36.3	7.4	27.1	10.6	37.7	7.7

TABLE XV.—*Average quantity per family and per person of the various articles of food consumed, the average quantity furnished by the farm, and the quantity bought per family (950 families)*—Continued.

FRUITS—Continued.

State.	Grapes (pounds).				Pineapples (number).							
	Per family.				Per family.				Per family.			
	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.
Vt.	......	9.7	9.7	2.0	......	......	......	......	......	......	......	......
Me.	17.2	5.1	22.3	5.0	......	10.7	10.7	2.4	......	......	......	......
N. Y.	5.1	3.3	8.4	2.1	......	......	......	......	......	......	......	......
Pa.	14.0	......	14.0	2.7	......	......	......	......	......	......	......	......
N. J.	37.7	3.3	41.0	8.7	......	40.0	40.0	8.5	......	......	......	......
N. C.	76.5	......	76.5	17.0	......	......	......	......	......	......	......	......
Ga.	......	......	......	......	......	......	......	......	......	......	......	......
Tex.	......	......	......	......	......	......	......	......	......	......	......	......
Ohio.	11.5	......	11.5	2.8	......	......	......	......	......	......	......	......
Wis.	9.2	.5	9.7	2.2	......	......	......	......	......	......	......	......
Iowa.	42.3	4.2	46.5	11.0	......	......	......	......	......	......	......	......
Kans.	20.3	18.0	38.3	8.5	......	......	......	......	......	......	......	......
N. Dak.	......	16.1	16.1	2.6	......	3.7	3.7	2.6	......	......	......	......
Cal.	10.8	72.0	82.8	16.9	......	2.4	2.4	.5	......	......	......	......

VEGETABLES.

State.	Irish potatoes (bushels).				Sweet potatoes (pounds).				Beans (pecks).			
Vt.	46.4	0.5	46.9	9.7	......	......	......	......	5.0	0.5	5.5	1.7
Me.	24.9	.5	25.4	5.7	......	48.2	48.2	10.8	17.2	5.5	22.7	5.1
N. Y.	31.8	.6	32.4	8.1	......	......	......	......	10.1	1.5	11.6	2.9
Pa.	25.1	1.9	27.0	5.2	......	......	......	......	13.2	.4	13.6	2.6
N. J.	35.7	1.5	37.2	7.9	894.4	47.1	941.5	199.9	24.8	.5	25.3	5.4
N. C.	8.1	.1	8.2	1.8	957.6	......	957.6	212.8	21.7	1.4	23.1	5.1
Ga.	8.0	.1	8.1	1.5	1,814.6	37.0	1,851.6	341.0	24.9	.5	25.4	4.7
Tex.	5.4	8.9	14.3	2.7	1.8	173.1	174.9	33.0	3.8	8.4	12.2	2.3
Ohio.	16.3	6.7	23.0	5.6	2.5	22.1	24.6	6.0	6.5	4.3	10.8	2.6
Wis.	36.7	1.1	37.8	8.6	......	......	......	......	2.8	1.6	4.4	1.0
Iowa.	30.6	1.6	32.2	7.6	......	25.0	25.0	5.9	3.5	4.2	7.7	1.8
Kans.	20.2	5.4	25.6	5.7	......	20.2	20.2	4.5	3.6	3.2	6.8	1.5
N. Dak.	59.6	1.2	60.8	9.8	......	3.1	3.1	.5	5.9	2.4	8.3	1.3
Cal.	4.1	16.6	20.7	4.2	......	70.6	70.6	14.4	9.8	9.4	19.2	3.9
	Peas (pecks).				Onions (pecks).				Cabbage (heads).			
Vt.	5.2	0.7	5.9	1.2	0.5	3.9	4.4	0.9	27.1	4.4	31.5	6.5
Me.	18.1	.2	18.3	4.1	.2	3.1	3.3	.8	17.9	7.3	25.2	5.6
N. Y.	4.7	.2	4.9	1.2	1.6	3.0	4.6	1.1	32.5	23.5	56.0	14.0
Pa.	4.3	.4	4.7	.9	3.2	.8	4.0	.8	82.6	5.3	87.9	16.9
N. J.	4.7	.4	5.1	1.1	4.8	1.3	6.1	1.3	79.3	11.9	91.2	19.4
N. C.	2.6	.1	2.7	.6	9.4	......	9.4	2.1	106.9	1.1	108.0	24.0
Ga.	8.1	......	8.1	1.5	6.9	.1	7.0	1.3	48.4	.5	48.9	9.0
Tex.	3.2	9.5	12.7	2.4	5.3	3.2	8.5	1.6	5.9	30.7	36.6	6.9
Ohio.	1.2	.4	1.6	.4	3.7	.4	4.1	1.0	44.7	.4	45.1	11.0
Wis.	.9	.4	1.3	.3	3.7	.7	4.4	1.0	76.6	......	76.6	17.4
Iowa.	2.7	1.5	4.2	1.0	2.6	2.0	4.6	1.1	32.3	12.5	44.8	10.6
Kans.	3.3	1.6	4.9	1.1	9.0	2.7	11.7	2.6	7.0	25.0	32.0	7.1
N. Dak.	4.8	.2	5.0	.8	4.4	.6	5.0	.8	45.0	.9	45.9	7.4
Cal.	1.5	1.9	3.4	.7	2.6	9.2	11.8	2.4	9.4	20.0	29.4	6.0

TABLE XV.—*Average quantity per family and per person of the various articles of food consumed, the average quantity furnished by the farm, and the quantity bought per family (950 families)*—Continued.

VEGETABLES—Continued.

State.	Turnips (pecks).				Beets (pecks).				Cucumbers (pecks).			
	Per family.				Per family.				Per family.			
	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.	Furnished.	Bought.	Total.	Per person.
Vt	5.7	0.8	6.5	1.4	3.9	0.1	4.0	0.8	6.0	0.5	6.5	1.3
Me	4.2	.4	4.6	1.0	5.7	......	5.7	1.3	10.7	......	10.7	2.4
N. Y	3.4	.6	4.0	1.0	.2	.1	.3	.1	4.8	.7	5.5	1.4
Pa	5.2	......	5.2	1.0	5.5	......	5.5	1.1	3.5	.1	3.5	.7
N. J	3.4	1.2	4.6	1.0	4.2	1.0	5.2	1.1	2.0	.3	2.3	.5
N. C	5.0	......	5.0	1.1	5.0	......	5.0	1.1	1.4	......	1.4	.3
Ga	17.1	.2	17.3	3.2	1.6	......	1.6	.3	......	......	......	......
Tex	30.0	16.1	46.1	8.7	1.9	.2	2.1	.4	......	......	......	......
Ohio	36.5	......	36.5	8.9	2.6	......	2.6	.5	3.7	......	3.7	.7
Wis	1.3	......	1.3	.3	1.8	......	1.8	.4	6.2	......	6.2	1.4
Iowa	1.5	.7	2.2	.5	3.3	.1	3.4	.8	2.1	.1	2.2	.5
Kans	1.5	.3	1.8	.4	2.7	......	2.7	.6	1.3	.1	1.4	.3
N. Dak	3.1	......	3.1	.5	5.0	......	5.0	.8	10.5	.7	11.2	1.8
Cal	2.2	6.1	8.3	1.7	.2	1.8	2.0	.4	4.6	4.2	8.8	1.8

State.	Tomatoes (pecks).				Sweet corn (dozens).				Squash (pounds).			
Vt	0.6	2.2	2.8	0.6	1.1	4.6	5.7	1.2	29.0	......	29.0	6.0
Me	10.6	.2	10.8	2.4	40.4	.4	40.8	9.2	66.9	......	66.9	15.0
N. Y	9.4	.6	10.0	2.5	20.4	2.8	23.2	5.8	26.0	......	26.0	6.5
Pa	20.4	......	20.4	3.9	40.4	1.2	41.6	8.0	......	......	......	......
N. J	47.1	......	47.1	10.0	43.7	.9	44.6	9.5	......	......	......	......
N. C	27.0	......	27.0	6.0	46.3	.5	46.8	10.4	......	......	......	......
Ga	20.0	3.8	23.8	4.4	28.6	4.3	32.9	6.1	......	......	......	......
Tex	2.7	12.1	14.8	2.8	7.9	17.5	25.4	4.8	......	......	......	......
Ohio	17.1	.9	18.0	3.4	1.9	25.1	27.0	5.1	......	......	......	......
Wis	8.8	.4	9.2	2.1	16.4	3.8	20.2	4.6	......	......	......	......
Iowa	14.4	.9	15.3	4.1	24.0	10.3	34.3	8.1	......	......	......	......
Kans	13.7	6.5	20.2	4.5	4.1	2.7	6.8	1.5	......	......	......	......
N. Dak	17.6	.4	18.0	2.9	22.9	......	22.9	3.7	18.6	......	18.6	3.0
Cal	8.6	13.0	21.6	4.4	13.8	6.8	20.6	4.2	21.6	32.3	53.9	11.0

State.	Carrots (pecks).				Melons (number).			
Vt	2.4	......	2.4	0.5	......	......	......	......
Me	......	......	......	......	......	......	......	......
N. Y	......	......	......	......	......	......	......	......
Pa	3.7	......	3.7	.7	......	......	......	......
N. J	......	......	......	......	126.6	5.3	131.9	28.0
N. C	......	......	......	......	67.5	......	67.5	15.0
Ga	......	......	......	......	108.6	......	108.6	20.0
Tex	......	......	......	......	......	......	......	......
Ohio	......	......	......	......	......	......	......	......
Wis	......	......	......	......	......	......	......	......
Iowa	......	......	......	......	18.8	6.6	25.4	6.0
Kans	......	......	......	......	72.0	......	72.0	16.0
N. Dak	3.1	......	3.1	.5	9.3	9.3	18.6	3.0
Cal	......	......	......	......	14.1	74.1	88.2	18.0

Tables XVI and XVII were prepared to bring to the attention of the reader more forcibly the articles most frequently bought and those most generally supplied by the farm in the different sections, and to point out more graphically the regional variations in these conditions.

TABLE XVI.—*Percentage of articles of food bought (950 families).*

Articles.	Vt.	Me.	N. Y.	Pa.	N. J.	N. C.	Ga.	Tex.	Ohio.	Wis.	Iowa.	Kans.	N. Dak.	Cal.
Coffee	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cocoa	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Tea	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sugar	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Salt	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Flour	100	100	100	95	100	71	100	100	99	100	34	97	100	100
Corn meal	100	100	100	53	100	14	33	76	33	100	91	100	100	100
Oatmeal	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Other cereals	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Graham flour	100	100	100	.....	.....	.....	.....	.....	.....	100	.....	.....	100	100
Rice	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Raisins	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sirups	26	100	55	100	100	56	42	100	100	68	100	100	100	100
Lemons	100	100	100	100	100	100	100	100	100	100	100	100	100	71
Oranges	100	100	100	100	100	100	100	100	100	100	100	100	100	80
Bananas	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Buckwheat	43	.....	38	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pork	21	25	34	15	22	1	1	18	6	10	2	7	8	39
Beef	39	14	61	68	92	78	48	100	50	52	49	35	35	97
Poultry	.....	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1
Fish	100	97	100	100	100	100	100	100	100	100	100	100	100	100
Buttermilk	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cream	.....	.....	.....	.....	12	.....	.....	.....	.....	.....	.....	.....	1	.....
Milk	.....	1	.....	1	8	.....	.....	2	.....	5	.....	.....	1	17
Butter	52	43	64	42	31	1	.....	.....	7	40	2	6	9	36
Cheese	100	98	86	58	84	100	78	100	77	100	100	16	80	87
Eggs	.....	3	5	.....	.....	.....	.....	.....	.....	2	.....	.....	.....	1
Honey	100	53	78	50	14	12	10	46	63	70	34	15	100	69
Apples	17	2	.....	24	17	6	16	100	36	26	20	34	95	33
Peaches	100	83	100	75	43	1	6	100	50	100	96	40	100	30
Plums	95	32	100	6	50	.....	.....	.....	20	100	5	.....	47	.....
Pears	92	25	31	5	3	.....	.....	100	10	77	71	64	100	13
Berries	70	18	32	8	30	.....	30	100	28	8	35	33	58	74
Cherries	.....	14	100	12	10	.....	.....	.....	17	9	15	9	53	28
Grapes	100	23	39	.....	8	.....	.....	.....	.....	5	9	47	100	87
Pineapples	.....	100	.....	.....	100	.....	.....	.....	.....	.....	.....	.....	100	100
Prunes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13
Potatoes, Irish	1	2	2	7	4	1	1	62	29	3	5	21	2	80
Potatoes, sweet	.....	100	.....	.....	5	.....	2	99	90	.....	100	100	100	100
Beans	9	24	13	3	2	6	2	69	40	36	55	47	29	49
Peas	12	1	5	8	7	1	.....	75	27	32	35	33	4	56
Onions	89	94	68	21	21	.....	1	38	11	15	44	23	12	78
Cabbage	14	29	42	6	13	1	1	84	1	.....	28	78	2	68
Turnips	12	8	16	.....	27	.....	1	35	.....	.....	30	14	.....	74
Beets	3	.....	15	.....	20	.....	.....	10	.....	.....	3	.....	.....	89
Cucumbers	8	.....	12	1	14	.....	.....	.....	.....	.....	4	3	6	48
Tomatoes	80	2	6	.....	.....	.....	16	82	5	4	6	32	2	60
Sweet corn	81	1	12	3	2	1	13	69	7	19	30	40	.....	33
Squash	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	60
Carrots	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Melons	.....	.....	.....	.....	4	.....	.....	.....	.....	.....	26	.....	50	84

TABLE XVII.—*Percentage of articles of food furnished by farm (950 families).*

Articles.	Vt.	Me.	N. Y.	Pa.	N. J.	N. C.	Ga.	Tex.	Ohio.	Wis.	Iowa.	Kans.	N. Dak.	Cal.
Coffee	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cocoa	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Tea	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sugar	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Salt	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Flour	.....	.....	.....	5	.....	29	.....	.....	1	.....	66	3	.....	.....
Corn meal	.....	.....	.....	47	.....	86	67	24	67	.....	9	.....	.....	.....
Oatmeal	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Other cereals	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Graham flour	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Rice	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Raisins	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sirups	74	.....	45	.....	.....	44	58	.....	.....	32	.....	.....	.....	.....
Lemons	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29
Oranges	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20
Bananas	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Buckwheat	57	.....	62	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pork	79	75	66	85	78	99	99	82	94	90	98	93	92	61
Beef	61	86	39	32	8	22	52	.....	50	48	51	65	65	3
Poultry	100	99	99	100	100	100	100	100	100	100	100	100	100	99
Fish	.....	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Buttermilk	.....	.....	.....	.....	.....	100	100	100	.....	.....	.....	.....	.....	.....
Cream	100	100	100	.....	88	.....	.....	.....	100	.....	100	100	99	.....
Milk	100	99	100	99	92	100	100	98	100	95	100	100	99	83
Butter	48	57	36	58	69	99	100	100	93	60	98	94	91	64
Cheese	.....	2	14	42	16	.....	22	.....	23	.....	.....	84	20	13
Eggs	100	97	95	100	100	100	100	100	100	98	100	100	100	99
Honey	.....	47	22	50	86	88	90	54	37	30	66	85	.....	31
Apples	83	98	100	76	83	94	84	.....	64	74	80	66	5	67
Peaches	.....	17	.....	25	57	99	94	.....	50	.....	4	60	.....	70
Plums	5	68	.....	94	50	.....	100	.....	80	.....	95	.....	53	100
Pears	8	75	69	95	97	100	100	.....	90	23	29	36	.....	87
Berries	30	82	68	92	70	100	70	.....	72	92	65	67	42	26
Cherries	.....	86	.....	88	90	.....	.....	.....	83	91	85	91	47	72
Grapes	.....	77	61	100	92	100	.....	.....	100	95	91	53	.....	13
Pineapples	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Prunes	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	87
Potatoes, Irish	99	98	98	93	96	99	99	38	71	97	95	79	98	20
Potatoes, sweet	.....	.....	.....	.....	95	100	98	1	10	.....	.....	.....	.....	.....
Beans	91	76	87	97	98	94	98	31	60	64	45	53	71	51
Peas	88	99	95	92	93	99	100	25	73	68	65	67	96	44
Onions	11	6	32	79	79	100	99	62	89	85	56	77	88	22
Cabbage	86	71	58	94	87	99	99	16	99	100	72	22	98	32
Turnips	88	92	84	100	73	100	99	65	100	100	70	86	100	26
Beets	97	100	85	100	80	100	100	90	100	100	97	100	100	11
Cucumbers	92	100	88	99	86	100	.....	.....	100	100	96	97	94	52
Tomatoes	20	98	94	100	100	100	84	18	95	96	94	68	98	40
Sweet corn	19	99	88	97	98	99	87	31	93	81	70	60	100	67
Squash	100	100	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	100	40
Carrots	100	.....	100	100	.....	.....	.....	.....	.....	.....	.....	.....	100	.....
Melons	.....	.....	.....	.....	96	100	100	.....	.....	.....	74	100	50	16

A general résumé of the average quantities of each article of food consumed per person and per family for all the families visited is given in Table XVIII. There is considerable difference between the diets of the families in the Southern States and those in the Northern and Western States. The southern families, for instance, use large quantities of buttermilk and sweet potatoes and relatively less of whole milk and Irish potatoes. This table, therefore, is divided into 2 groups, separating the averages of the families in the 3 Southern and those in the 11 Northern and Western States. It shows the relative importance of each item of food in the average family's annual total food consumption; the per cent bought and that furnished by the farm is also shown for each article of food.

TABLE XVIII.—*Average annual consumption of various articles of food (950 families).*

Articles and units.	Average of 150 families visited in three Southern States.				Average of 800 families visited in 11 Northern and Western States.			
	Quantities consumed.		Percentage of total.		Quantities consumed.		Percentage of total.	
	Per person.	Per family.	Bought.	Furnished by farm.	Per person.	Per family.	Bought.	Furnished by farm.
Groceries:								
Bananas...dozen	1.3	6.5	100		3.0	13.8	100	
Bread bought...pounds	4.5	23.9	100		41.6	194.8	100	
Buckwheat...do					4.9	21.1	56	44
Cocoa...do	.3	1.7	100		1.1	5.7	100	
Coffee...do	7.7	39.0	100		8.2	38.4	100	
Corn meal...do	97.9	502.1	41	59	10.9	50.4	89	11
Flour...do	250.3	1,253.4	90	10	195.1	913.2	93	7
Graham flour...do					2.0	10.2	100	
Lemons...dozen	.5	2.6	100		1.4	6.4	97	3
Oatmeal...pounds	3.8	20.0	100		15.4	69.7	100	
Other cereals...do	.8	3.9	100		5.2	23.8	100	
Oranges...dozen	.6	3.3	100		2.0	9.3	98	2
Raisins...pounds	3.2	16.7	100		5.4	24.8	100	
Rice...do	5.7	28.9	100		4.6	21.8	100	
Salt...do	4.4	22.5	100		12.5	60.4	100	
Sirups...gallons	3.0	15.6	66	34	1.8	8.2	86	14
Sugar...pounds	60.3	305.5	100		86.8	402.5	100	
Tea...do	.3	1.4	100		1.5	7.4	100	
Meat products:								
Beef...do	16.1	83.8	75	25	59.5	283.9	54	46
Fish...do	1.5	7.6	100		10.8	51.7	100	
Lard bought...do	2.9	15.3	100		5.5	26.2	100	
Pork...do	132.1	672.9	7	93	114.3	536.8	17	83
Poultry products:								
Poultry...do	58.0	296.8		100	45.4	207.1		100
Eggs...dozen	30.8	157.2		100	33.6	156.8	1	99
Dairy products:								
Butter...pounds	45.6	233.1		100	30.6	143.4	30	70
Buttermilk...quarts	388.6	1,984.1		100				
Cheese...pounds	1.0	5.3	93	7	3.9	18.5	81	19
Cream...quarts					6.6	32.6	2	98
Milk...do	68.9	331.1	1	99	196.9	917.5	3	97
Honey...pounds	1.8	9.3	23	77	1.3	6.0	59	41
Fruits:								
Apples...bushels	1.8	8.7	41	59	3.0	13.7	28	72
Berries...quarts	15.4	72.7	43	57	10.6	48.4	36	64
Cherries...do					7.4	33.5	27	73
Grapes...pounds	5.7	25.5		100	5.9	27.3	38	62
Peaches...do	90.4	457.7	36	64	21.8	103.2	74	26
Pears...do	15.3	73.3	33	67	11.2	54.7	45	55
Pineapples...number					1.1	5.2	100	
Plums...pounds	1.0	5.4		100	5.4	26.8	46	54
Vegetables:								
Beans...pecks	4.0	20.2	26	74	2.7	12.4	28	72
Beets...do	.6	2.9	3	97	.7	3.5	12	88
Cabbage...heads	13.3	64.5	29	71	11.1	51.4	26	74
Carrots...pecks					.2	.9		100
Cucumbers...do	.1	.5		100	1.2	5.6	9	91
Melons...number	11.7	58.7		100	6.5	30.6	33	67
Onions...pecks	1.7	8.3	13	87	1.2	5.8	43	57
Peas...do	1.5	7.8	38	62	1.2	5.4	20	80
Potatoes, Irish...bushels	2.0	10.2	21	79	7.1	33.5	14	86
Potatoes, sweet...pounds	195.6	994.7	34	66	22.0	103.2	85	15
Squash...do					3.8	17.7	12	88
Sweet corn...dozen	7.1	35.0	28	72	5.5	26.2	21	79
Tomatoes...pecks	4.4	21.9	33	67	3.7	21.3	18	82
Turnips...do	4.3	22.8	12	88	1.6	7.1	16	84

RELATIVE CONSUMPTION OF FOOD BY FAMILIES ON OWNED AND RENTED FARMS.

For all areas where the number of tenants was sufficient to warrant the division, the families were divided into two groups, those living on their own farms and those renting farms. Table XIX shows figures for these divisions, giving the average size of family, the average consumption of food per person, and the percentage of the food bought and furnished by the farm. There seems to be a slight tendency for the owner families to be larger than the tenant families, though it is not sufficiently marked to warrant further mention of it, the average of the 601 owner families visited being 4.8 persons and that of the tenant families 4.7 persons.

The difference between the two groups in the consumption of food per person is more pronounced. With the exception of the Maine and Iowa areas, the owner families use more food per person than the families renting farms. The average consumption per person of all the families living on their own farms is $100.60 and that of the tenant families is $90.57, a difference of $10 per person and $48 per family. The reason for this difference is probably, in part, that the owner families are as a class better off than the tenant families.

The tenants seem to buy a slightly greater proportion of their food than do the owners. This fact does not hold true in all the areas, but the average for the 11 areas studied shows that the owner families buy 40 per cent of the food they use and the tenants about 43 per cent. This slight variation may not have any significance, but it is probably true that for a series of years the fruit trees and gardens on the average tenant farm do not receive the attention they do on the farms operated by owners. The tenant's first care is his rent, and he may devote more time to his crops and live stock than to the farm food products for family use.

TABLE XIX.—*Comparison of food used on ownea and on rented farms, showing part bought and part furnished by the farm.*

County and State.	Tenure.	Number of families.	Average size of family.	Total consumption per person.	Percentage of total food—	
					Bought.	Furnished by farm.
Oxford, Me	Owners	139	4.5	$94.72	52.6	47.4
	Tenants	9	3.6	97.87	62.2	37.8
Otsego, N. Y	Owners	45	4.0	93.95	49.2	50.8
	Tenants	10	4.0	93.24	49.8	50.2
Gloucester, N. J	Owners	94	4.4	122.56	51.9	48.1
	Tenants	32	5.5	73.13	55.4	44.6
Gaston, N. C	Owners	44	4.4	93.80	16.3	83.7
	Tenants	11	4.9	71.81	24.3	75.7
Troup, Ga	Owners	36	5.7	89.82	20.6	79.4
	Tenants	14	4.9	84.22	25.2	74.8
McLennan, Tex	Owners	21	5.7	93.88	43.6	56.4
	Tenants	23	5.4	83.70	43.7	56.3
Champaign, Ohio	Owners	25	4.0	92.39	33.0	67.0
	Tenants	19	4.2	90.93	34.2	65.8
Montgomery, Iowa	Owners	32	4.5	102.71	32.2	67.8
	Tenants	14	3.5	111.36	35.4	64.6
Cloud, Kans	Owners	29	4.4	103.73	35.5	64.5
	Tenants	17	4.7	92.90	34.1	65.9
Cass, N. Dak	Owners	71	6.5	109.85	41.5	58.5
	Tenants	38	5.7	101.08	43.4	56.6
Santa Clara, Cal	Owners	65	4.9	103.27	64.7	35.3
	Tenants	19	5.1	95.97	64.8	35.2
All families	Owners	601	4.8	100.60	40.1	59.9
	Tenants	206	4.7	90.57	42.9	57.1

CANNING ON THE FARM.

Canning is an important means of preserving and storing fruits and vegetables on the farm for future use. The average number of quart cans "put up" per family for the farms visited (Table XX) was 122 of fruit and 32 of vegetables, making a total of 154 quart cans. The most canning was done in the New Jersey area, the average family here "putting up" 172 quarts of fruit and 58 quarts of vegetables, or a total of 230 quart cans.

Not many vegetables are canned on the farm. The most common vegetable used for this purpose is the tomato. Canned peas and corn used on the farm table are usually bought. This is probably due to the fact that efficient canning methods for handling vegetables are not known to many housekeepers.

The most common fruits used for home canning are peaches and berries. Many farmers buy peaches for canning purposes, but peaches are not generally bought for immediate use unless the price happens to be unusually low. An increase in the variety and quantity of home-grown fruit would greatly increase the consumption of fresh fruit on the farm and encourage canning for winter consumption.

A knowledge of better methods of canning, insuring better keeping qualities and greater ease of performing the work, would no doubt increase canning on the farm to good advantage, particularly in the case of vegetables. Housekeepers generally realize that it is cheaper to can home-grown products than it is to buy them and also insures better quality, but with the old method the many hours of extra labor before a hot stove is a big discouraging factor.

TABLE XX.—*Average number of quart cans "put up" on the farm.*

County and State.	Fruit.		Vegetables.		Total.	
	Per family.	Per person.	Per family.	Per person.	Per family.	Per person.
Gloucester, N. J.	172	37	58	12	230	49
Oxford, Me	62	14	21	5	83	19
Cass, N. Dak.	105	17	28	5	133	22
Santa Clara, Cal.	149	30	20	4	169	34
Average, all families	122	24	32	6	154	31

STORAGE OF FOOD ON THE FARM.

The farm is not only a source of food products, but it also serves as an ample place of storage. It is not possible to have fresh vegetables and fruits on hand every day, as it is eggs and milk. In order, then, to have vegetables and fruits from the farm at times other than the short period during which they are in season, some means of storage is necessary. Cellars, caves, pits, and basements in barns serve as storage places for vegetables and fruits. Probably as much as 30 per cent of the vegetables furnished by the farm are stored for later use by the farm family, and potatoes, the most important vegetable, are stored for at least nine months of the year in sections other than the South. Apples may easily be stored for six months.

Sweet potatoes, cabbages, white beans, beets, and onions may be stored for some time without any special preparation. Some vegetables and fruits are dried and kept in this form. Many families store their fruits and vegetables and find it unnecessary to buy at any time of the year.

About 30 per cent of the meat consumed by the farmers is meat that is supplied by the farm and stored for a certain length of time. This is made possible by the several available methods of curing. The most common method of curing meat is smoking. A special room or building is needed for this process, but the fuel used is generally wood of little value. There seems to be a tendency to do less curing of meat on the farm, owing probably to efforts to eliminate house labor.

A scheme for having a farm supply of fresh meat during the summer months is practiced in certain communities. A "beef club" is organized among a dozen or more farmers who trade beef. A member will butcher a beef animal, and it will be distributed equally among the members. The other members will take turns in supplying an animal in other weeks. When a difference in quantity occurs between members it is equalized at a fair rate per pound. They may have a butcher who gets the hide and tallow for his work. By this system the farmers can have fresh beef during the summer at farm prices.

FUEL.

The farm serves as an important source of fuel for the average farm family. Fifty-four per cent (Table XXI) of the fuel used by the families visited was supplied by the farm. The average value of the fuel used per family was $55.14. This, however, does not include kerosene used by occasional families for cooking during the summer.

The average consumption of coal was 2.6 tons per family. In the North Dakota area the average family used 3.7 tons of hard coal and 3.1 tons of soft coal. In addition to the wood and coal used, as indicated in Table XXI, the average family in the Kansas area used 12 loads of corncobs, and in the Iowa area 7.8 loads.

TABLE XXI.—*Average annual consumption of fuel and oil per family; percentage of fuel bought and furnished by farm (950 families).*

Location of regions in which study was made (county and State).	Coal.		Wood.		Total fuel.			Oil.	
	Tons.	Value.	Cords.	Value.	Value.	Bought.	Furnished by farm.	Gallons.	Value.
						Per ct.	*Per ct.*		
Oxford, Me	0.9	$6.39	13.5	$46.40	$52.79	74	26	63.0	$7.56
Lamoille, Vt	.1	1.01	14.3	65.40	66.41	4	96	39.0	4.61
Otsego, N. Y	2.5	16.00	12.3	54.80	70.80	24	76	56.6	5.79
Bucks, Pa	4.9	26.90	6.2	19.00	45.90	61	39	63.0	6.37
Gloucester, N. J	4.7	30.69	5.6	20.91	51.60	70	30	92.0	9.20
Gaston, N. C	....	....	14.0	43.58	43.58	4	96	22.0	3.10
Troup, Ga	....	....	17.8	51.60	51.60	....	100	34.5	5.18
McLennan, Tex	2.0	17.35	6.1	19.30	36.65	89	11	55.4	7.58
Champaign, Ohio	5.7	23.70	12.0	32.50	56.20	46	54	50.0	4.88
Jefferson, Wis	3.0	20.70	7.5	38.80	59.50	40	60	46.7	5.78
Montgomery, Iowa	3.9	29.57	4.8	22.40	[1] 59.77	49	51	56.0	6.92
Cloud, Kans	1.4	12.70	4.9	12.20	[2] 31.00	42	58	81.4	7.21
Cass, N. Dak	[3] 6.8	62.00	5.6	38.75	100.75	83	17	61.3	7.97
Santa Clara, Cal	.3	2.84	7.4	42.58	45.42	56	44	53.0	6.36
Average, all families	2.6	17.85	9.4	36.30	55.14	46	54	55.3	6.33

[1] Includes $7.80 worth of cobs.
[2] Includes $6.10 worth of cobs.
[3] 3.7 tons hard coal and 3.1 tons soft coal.

The consumption of wood per family and per person is shown in Table XXII. The average quantity of wood used per family is 9.4 cords. The farm supplied, on an average, 8.2 cords and 1.2 cords were bought. The farm thus furnishes 87 per cent of the wood used for the families visited. The farm wood lot, the orchard, and scattered trees on the farm furnish the wood for the wood stove.

TABLE XXII.—*Annual consumption of wood per family and per person (950 families).*

Location of regions in which study was made (county and State).	Consumption per family.			Consumption per person.
	Total.	Bought.	Furnished by farm.	
	Cords.	*Cords.*	*Cords.*	*Cords.*
Oxford, Me	13.5	0.9	12.6	3.0
Lamoille, Vt	14.3	.4	13.9	3.0
Otsego, N. Y	12.3	.2	12.1	3.1
Bucks, Pa	6.2	.4	5.8	1.2
Gloucester, N. J	5.6	1.4	4.2	1.2
Gaston, N. C	14.0	.6	13.4	3.1
Troup, Ga	17.8	....	17.8	3.3
McLennan, Tex	6.1	4.8	1.3	1.1
Champaign, Ohio	12.0	.7	11.3	2.9
Jefferson, Wis	7.5	.6	6.9	1.1
Montgomery, Iowa	4.8	....	4.8	1.7
Cloud, Kans	4.9	.1	4.8	1.1
Cass, N. Dak	5.6	3.1	2.5	.9
Santa Clara, Cal	7.4	3.9	3.5	1.5
Average, all families	9.4	1.2	8.2	2.0

Kerosene oil is used both for lighting and cooking. Some gasoline was used for cooking but very little for lighting purposes. Of the 127 families visited in New Jersey, 78 used kerosene or gasoline stoves for cooking, 9 used acetylene gas and 4 electricity for lighting. In the Maine area 42 of the 148 families visited used kerosene stoves for cooking and kerosene was used exclusively for lighting. In North Dakota 54 of the 109 families used kerosene or gasoline for cooking, and for lighting 2 used acetylene and 1 used electricity. In California, of the 84 families interviewed, 30 used kerosene or gasoline stoves for cooking, and for lighting 8 used electricity and 2 used acetylene gas. We can thus see that nearly half of these farmers do some cooking with kerosene and gasoline, but that practically all of them use kerosene lamps for lighting.

USE OF HOUSE ON THE FARM.

The business of most farms demands almost constant attention throughout the year and it is therefore to the advantage of the farmer to make his home on the farm. A house is thus a necessary improvement on a farm, and is often an important part of its real estate value. Investigations made by the United States Department of Agriculture indicate that in the eastern part of the United States the value of the house is commonly 20 per cent or more of the value of the farm. On the higher-priced corn-belt farms this percentage is more generally from 5 to 10 per cent. Improvements to the house tend to enhance the value of the farm. The interest on the investment in the house and the cost of maintenance of it are paid for by the farm business, and are not personal expenses to the farmer. He may be said to have his house rent furnished free by the farm.

An attempt is made to arrive at a value of what the use of the house is worth to the farmer. The value of the house seems the only basis upon which the rental value can be determined.

Table XXIII shows the average value of the farmhouse and its rental value for the sections studied. The present value is the farmer's estimate of what his house is worth to-day. The average value of the farmhouses for the 825 farmers giving estimates was $1,322. This value, however, varies from $560 in the North Carolina area to $1,880 in the New York area.

The rental value of the house is taken as 10 per cent of its present value. This is assumed to be a fair charge for interest, depreciation, insurance, repairs, and taxes. The average annual rental value of the houses for these farms is thus $132.

TABLE XXIII.—*Average total value and annual rental value of farm dwellings.*

County and State.	Number of farm houses.	Average size of family.	Average value of house.	Average rental value of house.
Oxford, Me.	146	4.5	$1,112	$111
Lamoille, Vt.	31	4.7	930	93
Otsego, N. Y.	28	4.0	1,880	188
Bucks, Pa.	22	4.9	1,632	163
Gloucester, N. J.	126	4.7	1,600	160
Gaston, N. C.	51	4.5	560	56
Troup, Ga.	40	5.4	920	92
McLennan, Tex.	42	5.3	834	83
Champaign, Ohio	34	4.1	1,724	172
Jefferson, Wis.	40	4.2	1,297	130
Montgomery, Iowa	37	4.2	1,580	158
Cloud, Kans.	36	4.7	1,160	116
Cass, N. Dak.	109	6.2	1,754	175
Santa Clara, Cal.	83	4.9	1,528	153
Average, all houses	825	4.7	1,322	132

THE SIZE OF THE HOUSE.

Table XXIV points out some interesting facts. The tabulation has been made by size of houses expressed in number of rooms. It will be seen that in all States the average size of family on farms having houses of from 8 to 9 rooms is markedly larger than on those having houses of 7 rooms or less. There is no consistent relationship between these two groups of families in the consumption of food or fuel per person.

Families living in 8 and 9 room houses and those living in 10-room houses show different relationships. Here the size of family is practically constant, showing that the large houses are not needed for the accommodation of more people. The quantity of food consumed per person on these farms increases directly with the size of house, and there is a tendency, though not very marked, for the greater consumption of fuel in the larger houses.

These facts would indicate that farmers living in the largest houses, and who also are the highest consumers of food and fuel, have better farm incomes and probably live on the farms of most efficient size.

Studies conducted by the United States Department of Agriculture indicate that on the farm the amount of money invested in the house is in direct proportion to the income up to a certain point.

TABLE XXIV.—*Relation of size of house to size of farm, size of family, food consumption per person, and value of house.*

County and State.	Size of house (rooms).	Number of farms.	Average size of farm (acres).	Persons per family.	Consumption of food per person.	Average value of house.
Gloucester, N. J.	7 and less	32	38	3.7	$152.52	$987
	8 and 9	48	67	4.6	118.41	1,591
	10 and over	46	92	5.4	120.83	2,237
Oxford, Me.	7 and less	50	84	3.9	88.28	642
	8 and 9	48	109	4.8	92.30	1,091
	10 and over	48	148	4.7	102.80	1,624
Cass, N. Dak.	7 and less	56	333	5.5	103.51	998
	8 and 9	27	458	6.9	101.70	2,240
	10 and over	26	706	6.9	118.70	2,900
Santa Clara, Cal.	5 and less	25	48	4.1	91.24	738
	6 and 7	33	39	5.3	98.40	1,516
	8 and over	25	52	5.4	113.71	2,335

HOUSEHOLD LABOR.

The subject of household labor is included in this study, as it has an important bearing on the business operations of the farm. Conditions are generally such that the hired help have to board with the farm family. The housewife often cares for the family garden, does the laundry work for the household, and at times churns the butter. In doing so, she is contributing to the success of the farm, and is performing productive labor for that farm.

On the farms studied in this inquiry comparatively little help was hired for doing housework, most of the work being done by the farmer's wife and other members of the family. More than three-fourths of the families visited did not hire any labor for housework. Table XXV shows the average value of the house labor per family and per person for each section and the proportion of this hired. It will be noticed that on an average 5 per cent of the labor was hired, this per cent varying from 1 to 15.

The average value of the house labor for all families visited was $228 per family and $49 per person. This value was determined by securing the wife's estimate of what she would have to pay a housekeeper to do the work for her. These estimates were based on the prevailing wages of domestic help in each region.

One of the serious difficulties confronting the farmer's wife is the labor problem. Domestic help is hard to get and often inefficient when secured. Along with this problem goes that of boarding the hired man. The average hired man demands more meat and a greater variety of diet than the wife would go to the trouble of preparing as a regular thing if the family alone were to be served. A tenant house on the large farm, permitting the hiring of married help, would tend to solve the house labor problem.

TABLE XXV.—*Value of household labor per family and per person; percentage of labor hired (950 families).*

County and State.	Value of labor.		Percentage of labor hired.
	Per family.	Per person.	
Oxford, Me	$238	$53	3
Lamoille, Vt	182	38	1
Otsego, N. Y	221	56	3
Bucks, Pa	214	41	1
Gloucester, N. J	294	63	9
Gaston, N. C	152	34	5
Troup, Ga	138	25	15
McLennan, Tex	217	41	7
Champaign, Ohio	197	49	3
Jefferson, Wis	177	54	1
Montgomery, Iowa	270	64	3
Cloud, Kans	261	58	1
Cass, N. Dak	334	54	7
Santa Clara, Cal	293	60	8
Average, all families	228	49	5

VALUE OF BOARD ON THE FARM.

A general indication of the value of board on the farm may be gained from the data given on the previous pages, showing also what proportion of this cost may be credited to the farm and what proportion is paid out in cash. This should be of help in determining the real wages of hired help boarded on the farm when given a definite cash wage and board.

The main items entering into this cost are food, fuel, and household labor. All food consumed must be charged to board. Some of the fuel is used for general heating purposes; therefore, total fuel cost can not justly be included in board charges. Probably two-fifths of the fuel consumed may be said to be used for the preparation of meals or kitchen stove purposes. Household labor is included as a factor in the cost of meals because it plays a very vital part in the preparation of meals and is too generally unappreciated when the matter of boarding hired help is being considered. Two-thirds of the value of household labor seems to be a fair proportion to charge to the cost of board.

Table XXVI shows the cost of food, fuel, and house labor per person chargeable to the cost of board. It will be noticed that food constitutes nearly three-fourths of the cost of board, labor nearly one-fourth, and fuel about 3 per cent. The total cost of board per person varies from $9 to $13 per month. The variation in the cost of board, of course is dependent largely on the cost of the food consumed.

TABLE XXVI.—*Average annual value of food, fuel, and household labor per person chargeable to the cost of board on the farm (950 families).*

Location of regions in which study was made (county and State).	Average value per person.			Total cost of board per person.		Percentage paid out in cash.
	Food.	Fuel.	House labor.	Annual.	Monthly.	
Oxford, Me	$95	$5	$32	$132	$11.00	39
Lamoille, Vt	75	6	23	104	8.67	34
Otsego, N. Y	94	7	34	135	11.25	35
Bucks, Pa	75	4	25	104	8.67	35
Gloucester, N. J	120	4	38	162	13.50	40
Gaston, N. C	89	4	20	113	9.41	15
Troup, Ga	89	4	15	108	9.00	19
McLennan, Tex	92	3	25	120	10.00	36
Champaign, Ohio	91	5	29	125	10.42	25
Jefferson, Wis	80	5	32	117	9.75	28
Montgomery, Iowa	106	6	38	150	12.50	24
Cloud, Kans	100	3	35	138	11.50	26
Cass, N. Dak	107	6	32	145	12.08	34
Santa Clara, Cal	102	4	36	142	11.83	49
Average, all families	94	5	30	129	10.68	31

A very interesting fact brought out in Table XXVI is the proportion of the cost of board actually paid out in cash. This percentage varies from 15 to 49. The proportion is about one-third in the eastern sections studied, about one-fourth in the corn-belt States areas, and still less in the southern areas. This amount paid out is the fact which most vitally interests the farmer.

Interesting facts are brought out in this connection relative to total hired help boarded. For example, in New Jersey hired help averaged 0.6 person per family; in Maine, 0.4; in North Dakota, 1.1; and in California 0.3. In other words, in New Jersey the average family boarded 1 man for 7 months; in Maine, 1 man for 5 months; in North Dakota, 1 man for 13 months; and in California 1 man for 4 months.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 411
OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. Spillman, Chief

Washington, D. C. PROFESSIONAL PAPER September 14, 1916

SYSTEMS OF RENTING TRUCK FARMS IN SOUTHWESTERN NEW JERSEY.

By HOWARD A. TURNER, *Scientific Assistant.*

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cation and description of the area	2	Farms let for half of the crops and half of the milk	13
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The facts on which this discussion is based were collected in the ummer of 1914 in a truck-farming area in southwestern New Jersey. he purpose of the study was to make a comparative analysis of the ethods of renting in vogue in such an area, to find the sources and nounts of the expenses and income, how they were divided between ndlord and tenant, and what kind and how much capital was rnished by each party to the contract. Tenants to the number of 6 were visited on their farms and inquiries made of them concerning ethods of renting, capital employed, crops grown, and the receipts d expenses for the crop year 1913. The records secured are presentative of the section, and include a number of farms under ch system of renting for each of two types of truck farming, early d late. On many of these farms dairying is combined with trucking.

RESULTS.

It was found that the method of renting in most common use is e half-share system, under which the tenant furnishes labor, teams, tock, and tools, and gives as rent half the grain and half of the turns from truck and other crops sold, but none of the receipts om live stock. In the case of the larger and more desirable truck d dairy farms the landlord gets half of the returns from the dairy, addition to half of the returns from all sales of crops. A few farms rented for cash and occasionally one for a share other than half.

Following is a brief summary of the more significant averages brought out by this study:

Averages for 186 farms let for half share of crops:
  Labor income of tenant,[1] $323.
  Landlord's interest on investment, 6.8 per cent (equivalent to a cash rent of $7.11 per acre).
Averages for 12 farms let for half share of crops and of returns from dairy:
  Labor income of tenant, $715.
  Landlord's interest on investment, 7.7 per cent (equivalent to a cash rent of $8.95 per acre).
Averages for 35 farms let for cash rent:
  Labor income of tenant, $206.
  Landlord's interest on investment, 3.7 per cent (equivalent to a cash rent of $4.32 per acre).

It was found that the labor income of the tenant and the per cent received by the landlord on his investment are subject to greater variations on farms raising early truck than on farms raising late truck.

A majority of the farmers visited considered the returns of the year of the survey (1913) as somewhat below normal.

LOCATION AND DESCRIPTION OF THE AREA.

The farms from which records were secured are in Gloucester, Salem, and Cumberland Counties, within the area between the Delaware River on the west and north and a line on the east drawn north and south from Woodbury to Bridgeton. The soil[2] of the northern portion of this area is chiefly of a type known as Sassafras sand, a rather loose sandy soil well adapted to the early-maturing truck crops that are grown on it. In the southern portion of the area the principal soil is Sassafras silt loam, a well-drained, friable loam. The farms in this southern section are of a general type, combining the production of market milk and the crops necessary to feed the stock with wheat and such crops as tomatoes for the cannery and early white potatoes. Marsh meadows, some of which have been reclaimed from the tides, form a part of many farms. These meadows afford pasturage, as well as large quantities of marsh-grass hay for forage and bedding purposes.

The West Jersey & Seashore Railroad serves the area with three branches which radiate from Woodbury, a city of 4,600, located in the northeastern corner of the area and 9.6 miles south of Philadelphia. There are frequent stops and sidings on these branches, and most of the truck and milk produced finds its outlet over these lines, although a few farmers near Philadelphia haul a part or all of their truck to that market by wagon, and some truck is transported by water. The Delaware River and its small tidal tributaries are used by scows and barges to transport stable manure from Philadelphia and other cities along the Delaware River to wharves in the early-trucking section and also to carry to the canneries in Baltimore that part of the tomato crop which the farmers do not find it profitable to crate. In this way the cost of manure is lessened and the early-truck farms are afforded an outlet for their surplus tomatoes, which might otherwise be lost, as but few farms on the light-soil type are located within short hauling distance of a cannery, while most of them are within easy reach of a landing. New York manure shipped in by rail is more expensive than Philadelphia manure, but it is used in large quantities by farmers located on the light soil and at a considerable distance from a wharf. The range in price paid for stable manure was from $1.45 to $2.45 a ton, the cost depending upon the kind, quantity, and time and conditions of purchase.

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[1] Labor income—that which the farmer has left as wages for his year's work after a fair rate of interest on the money he has invested in his farm enterprise has been deducted from his net returns.

[2] J. A. Bonsteel and F. W. Taylor, Soil Survey of the Salem Area, New Jersey, Field Operations of the Bureau of Soils for 1901, U. S. Department of Agriculture. J. A. Bonsteel, Soils of the Sassafras Series, U. S. Department of Agriculture Bulletin 159.

The dairy products are marketed in Philadelphia and also in Atlantic City and other seaside resorts, the milk from many farms which ship to Philadelphia in the winter being diverted to the seaside markets in the summer months.

RELATION OF PROFITS IN 1913 TO A NORMAL YEAR.

The profits of the crop year 1913 were less than normal, as indicated by estimates made by 167 tenants which are given in Table I.

Table I.—*Relation of profits in 1913 to a normal year.*

	Total number.	Per cent who considered profits in 1913 as being—		
		Above normal.	Normal.	Below normal.
All farms reporting	167	9	45	46
Early-truck farms	86	16	29	55
Late-truck farms	81	1	62	37

Among the reasons given for the incomes running below normal were late frosts, which destroyed many of the first settings of tomato plants, drought, small yields, and low prices.

CLASSIFICATION OF FARMS.

The 246 farm records have been divided into two groups, designated the "early" and the "late" truck farms. This division is made because of the differences in the type of farming on the Sassafras sand as compared with the Sassafras silt loam. The early-truck farms include 112 farms from which the sales of late tomatoes and white potatoes were exceeded by the sales of other truck crops. The late-truck farms include the 134 farms from which the sales of late tomatoes and white potatoes exceeded the sales of other truck crops. This method of separation places almost all the farms on the light soils among those classed as early-truck farms and almost all those on the heavier soils among the late-truck farms.

The most common method of letting land to tenants was found to be for half of the crops. Of 246 farms, 186 were let for half of the crops, 12 for half of the crops and half of the milk, 13 for a share other than half, and 35 for a cash rental. In Table II the farms are classified according to the type of farming and the method of renting.

TABLE II.—*Classification of farms according to type of farming and method of renting.*

Method of renting.	Number of farms.	
	Early-truck.	Late-truck.
Half share of crops	90	96
Half share of crops and of milk		12
Share other than half	9	4
Cash rental	13	22
All farms	112	134

ACREAGES AND VALUES OF CROPS.

Among both cash and share rented farms the average farm is larger and the average acreage in such general crops as corn, wheat, and hay is larger on the late-truck farms than on the early-truck farms. These crops are grown more generally on late-truck farms than on farms of the other type. Tomatoes are grown almost universally on farms of both types, although marketed differently on each. White potatoes are grown on half of the early-truck farms and in larger acreages on almost all the late-truck farms. Sweet potatoes are raised on but few farms of the latter type, but almost universally on the early-truck farms. On farms growing early truck, the more important truck crops, in addition to tomatoes, sweet potatoes, and white potatoes, are peppers, watermelons, cantaloupes, asparagus, eggplants, and strawberries. In Table III is shown the distribution and value of the more important crops, classified by type of tenure and type of farming.

TABLE III.—*Distribution and value of crops, classified by type of tenure and type of farming.*

Kind of truck grown.	Method of renting.					
	Half of crops.		Half of crops and of milk.	Share other than half.	Cash rent.	
	Early truck.	Late truck.	Late truck.[1]	Early and late truck.	Early truck.	Late truck.
Number of farms	90	96	12	13	22	13
Average acres per farm	97	112	156	91	72	87
Average acres in crops	60	76	99	61	40	53
Per cent of crop acreage in truck crops	51.7	28.3	23.1	43.1	52.4	28.4
Average acres in—						
Field corn	11	21	31	14	10	15
Wheat	1	7	12	2	1	6
Tame hay	10	16	30	14	5	14
Marsh hay	7	9	3	5	3	4
Tomatoes	12	6	4	8	7	3
White potatoes	4	15	18	7	2	12
Sweet potatoes	12	....	....	9	7	....
All other truck	4	....	1	2	5	....
Pasture	8	15	32	5	7	18
Number of farms growing nontruck crops	87	96	12	12	19	13
Farms growing corn	82	96	12	12	18	13
Farms growing wheat	7	53	9	3	1	7
Farms growing tame hay	77	95	12	12	11	13
Farms growing marsh hay	45	41	2	4	7	3
Number of farms growing truck crops	90	96	11	13	22	13
Farms growing tomatoes	89	80	7	11	22	10
Farms growing white potatoes	45	92	11	9	10	10
Farms growing sweet potatoes	83	2	1	9	19	....
Value of all crops per farm	$3,646	$2,991	$4,145	$3,208	$2,168	$1,978
Value of nontruck crops per farm	635	1,419	2,392	828	403	971
Value of nontruck crops per acre	22	26	31	24	21	26
Value of truck crops per acre	96	73	75	90	84	66

[1] One farm had no truck crops in 1913, but is included here for the reason that it usually grows such crops and is organized on that basis.

The value of truck crops per acre is greater on the early-truck farms than on the late-truck farms, but the value of nontruck crops per acre is greater on the late-truck farms. Of the two groups of farms let for a half share of the crops, on the early-truck farms the value of the nontruck crops is 17 per cent of the value of all crops and 47 per cent on the late-truck farms. The small production of nontruck crops on the early-truck farms tends to limit the animals that may profitably be kept in addition to the work stock. Manure is even more essential to profitable farming on the early-truck farms than on the late-truck farms, so that, while the latter with an average of 12.1 cows per farm depend largely on manure produced on the farm, the former with an average of 3.1 cows depend almost entirely upon purchased stable manure.

EARLY-TRUCK FARMS LET FOR HALF OF THE CROPS.

The customary arrangement on these farms is for the tenant to furnish all the work stock, productive stock, tools, machinery, and labor, while the landlord furnishes the use of the land and buildings, the commercial fertilizer and manure, and meets a part of some other expenses. The landlord receives a half of the grain produced and a half of the proceeds from sales of truck and other crops, but the tenant has all the receipts from live stock and live-stock products.

The sales of truck crops are divided equally on all farms. Where there was a field of asparagus the landlord in a few cases reserved this crop, furnishing the labor for it and securing all of the income.

Field corn was grown by 82 of the 90 half-crop tenants. Most of these tenants had a half of the corn, several had two-thirds, and 18 had all. On many farms the entire corn crop was insufficient to feed the few animals kept, so that the tenant seldom had any corn to sell. The landlord's share, where a share is reserved as rent, was sometimes sold to the tenant. The straw, corn fodder, and hay are kept on the farm and utilized by the tenant, who is encouraged by the landlord to make as much farm manure as possible. Not infrequently, when the hay or bedding produced on the place is insufficient for the tenant's stock, more is bought for him by the landlord. Where there is surplus hay to sell, as there was on eight farms, the proceeds are divided equally. On six farms the landlord required, as part of the rent, a share of the hay, but in only two cases as much as half. Of nontruck crops, including corn, corn fodder, wheat, straw, hay, and marsh hay, an average of $635 worth was produced on each farm, of which only $148 worth was sold, the landlord selling $131 worth.

On the 90 farms growing early truck crops the use of large quantities of manure is imperative, because of the light, sandy nature of the soil, which responds quickly to the application of manure, but quite as quickly loses its fertility. As but little live stock is kept on these farms, most of the manure used must be purchased. Commercial fertilizer was purchased on all these farms, and stable manure on all but three. The landlord in every case paid all the cost of the stable manure, which averaged $385 per farm on the 87 farms purchasing manure. The landlord paid the cost of all commercial fertilizer on 75 farms and a half or more on the other 15 farms.

It is often not practicable for the tenant to grow sufficient feed on the farm to provide for the needs of the stock kept, because of the necessity of devoting much of the small acreage to truck crops and because of the light nature of the soil and the resultant low yields of field crops. Grain bought is paid for by the tenant, since he has all of the income from stock. Hay or marsh grass for feeding, bedding, or litter purposes was purchased for their tenants by 41 landlords at an average cost of $75.

In Table IV is shown the variation as to practice in the sharing of the principal expenses. It will be seen that the landlord very frequently pays more than half of the cost of purchased fertility.

TABLE IV.—*Variation in practice as to sharing of expenses on 90 New Jersey early-truck farms rented for half of the crops.*

Items of expense.	Number of farms.				
	Having no such expense.	Method of sharing expense.			
		Landlord all.	Half and half.	Tenant all.	Other methods.
Feed and roughage	2	....	....	47	Landlord furnished a part or all of the roughage on 41 farms.
Seed potatoes (white)	46	....	42	2	
Grass and clover seed	30	12	47	1	
Fertilizer	....	[1] 75	[1] 7	....	Landlord furnishes all except half of white potato fertilizer on 6 farms. Tenant furnishes a little less than half on 2 farms.
Manure	3	87	....	....	
Crates and hampers	10	....	78	....	Tenant more than half on 1 farm and less than half on 1 farm.
Baskets (gathering)	....	2	44	44	
Spray material	28	3	43	14	Tenant furnishes more than half on 2 farms.
Tool and stock maintenance	....	....	....	90	
Labor	....	....	....	57	Landlord pays a part of the cost of picking on 33 farms.
Real-estate taxes	....	81	9	....	
Building maintenance	....	90	....	....	A few minor exceptions.

[1] On 1 farm the tenant furnished the potato fertilizer and the seed white potatoes and had the entire crop.

The expense for purchased seed was not large, except for the white potato crop. A few tenants grew a part of their seed white potatoes, but this is not a general practice. Tomato and melon seed, seed sweet potatoes, and seed wheat and corn are customarily saved by the tenant from the crops of the previous year. Where seed is bought it is usual for the landlord to pay half of the cost, but on some farms the cost of grass seed is paid entirely by the landlord.

The tenant is expected to raise the necessary tomato, sweet potato, pepper, melon, and other plants, and for the purpose of starting these the farms are equipped with flue-heated hotbeds. The wood used for fuel in these hotbeds is usually cut on the farm by the tenant, although in some instances fuel must be bought, in which case the tenant frequently pays half. Sash are used to cover such of these beds as are used in starting tomatoes, while straw, marsh grass, and cloth are commonly used to cover beds in which sweet potatoes are started. The sash may or may not be owned in common by landlord and tenant, but the landlord usually owns more than half. The tenant ordinarily makes the minor repairs on the sash owned by the landlord, but he is not expected to furnish the materials with which to make such repairs.

The tenant furnishes all labor for ordinary farm work, but the landlord frequently pays half of the cost of picking tomatoes for the cannery, especially when the price received per basket has dropped to 10 or 12 cents or less, but there would seem to be no definitely established practice in this respect. Tomatoes are sold in crates as long as a fair price can be obtained, and the remainder of the crop is sold for canning purposes. The price obtained for tomatoes sold to the canneries sometimes drops so low that when the tenant hires his picking done it becomes unprofitable for him to handle the crop for half, unless the landlord pays a part of the cost of picking. The price usually paid for picking cannery tomatoes is 1½ to 2 cents a basket. More is paid for the picking of early tomatoes for city markets, but this expense is paid entirely by the tenant.

The landlord pays a half of the cost of packages in which crops are sold. The tenant frequently furnishes all of the baskets in which crops are gathered and in which the tomatoes are carried to the canneries.

The tenant meets the cost of tool and stock maintenance. On 81 of the 90 early-truck farms the landlord paid all of the real-estate tax, and on the other farms the tenant paid half.

In Table V are summarized the average receipts and expenses of the 90 early-truck farms.

TABLE V.—*Landlord's and tenant's average receipts and expenses on 90 New Jersey early-truck farms rented for half of the crops.*

	Landlord.	Tenant.
Sources of receipts:		
Nontruck crops sold	$131	$17
Tomatoes	727	727
Sweet potatoes	536	536
White potatoes	63	64
Other sales of truck	184	171
Dairy products (3.3 cows)		126
Poultry and eggs		168
Other income from stock		64
Other receipts		7
Total receipts	1,641	1,880
Items of expense:		
Feed	34	238
Seed	35	33
Commercial fertilizer	350	23
Stable manure	372	
Packages	109	117
Spray material	7	8
Tool maintenance, estimated at 18 per cent on value		121
Sash maintenance, estimated at 10 per cent on value	21	8
Hired labor, board included	17	704
Family labor	1	162
Real-estate tax	71	4
Maintenance of buildings, estimated at 4 per cent on value	80	
Other expenses	2	59
Total expenses	1,099	1,477
Interest on landlord's capital	542	
Labor income of tenant and interest on his capital		403
Interest at 6 per cent on working capital [1] (landlord $535, tenant $2,398)	32	144
Labor income of tenant [2]		259
Interest on real estate (7.4 per cent on $6,909) [3]	510	
Equivalent cash rent per acre, $6.88.[4]		

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[1] *Working capital.*—The capital used to operate the farm, and consisting of work stock, productive stock, tools and machinery, sash, feed and supplies, and cash necessary to meet current farm expenses.

[2] *Labor income of the tenant.*—What he gets for his year's work in addition to the use of a house and farm food and fuel products. It is obtained by deducting from his receipts all his farm expenses, including the cost of hired labor, the value of family labor employed on farm work, whether paid or unpaid, and interest and maintenance charges on his working capital.

[3] *Interest on real estate.*—What the landlord gets for the year's use of the farm (land and buildings). It is obtained by deducting from his receipts all farm expenses met by him, including maintenance charges on his working capital and farm buildings and interest on his working capital.

[4] *Equivalent cash rent.*—Consists of interest on the real-estate investment, building maintenance, and all real-estate taxes, whether paid by owner or tenant.

Among any group of farms, taken without reference to merit, will be found a few that are much more successful than the average. The summary of a year's business on such a farm rented for half the crops on which early-truck crops are grown is given in Table VI.

TABLE VI.—*Summary of a year's business on a successful early-truck farm let for half of the crops.*

Acres in farm, 120; value of farm, $10,000; buildings alone, $3,000.
Working capital furnished by tenant, $3,225, consisting of stock (4 horses, 3 cows, 7 hogs, 40 hens), $1,125; machinery and tools, $1,200; feed and supplies, $300; cash, $600.
Working capital furnished by landlord, $1,260, consisting of 280 sash, fertilizer, manure, packages, etc.
Acres in pasture, 8.
Acres in nontruck crops, 25 (corn 15, hay 10); value of nontruck crops produced, $1,170; value of nontruck crops per acre, $47.
Acres in truck crops, 48; sales, $8,900; sales per acre in truck crops, $185.

	Landlord.	Tenant.
Sources of receipts:		
Nontruck crops sold (landlord's half corn)	$360	
Early tomatoes (10 acres)	1,500	$1,500
Second early tomatoes (11 acres)	750	750
Sweet potatoes (7 acres)	500	500
Peppers (2 acres)	400	400
Eggplants (2 acres)	350	350
Cantaloupes (4 acres)	150	150
Citrons (4 acres)	225	225
Cucumbers (2 acres)	75	75
Asparagus (6 acres)	500	500
Income from stock (eggs and butter)		28
Income from crops and stock	4,810	4,478
Items of expense:		
Feed		120
Fuel for hotbeds, coal		20
Seed	16	16
Commercial fertilizers, 30 tons	900	
Stable manure, 300 tons	900	
Crates and hampers	120	120
Baskets		50
Spray material	30	30
Tool maintenance, estimated at 18 per cent on value		216
Sash maintenance, estimated at 10 per cent on value	56	
Shoeing		20
Taxes and insurance on working capital		23
Special picking labor	70	70
Hired labor, board included		1,630
Family labor		
Real-estate tax	150	
Maintenance of buildings, estimated at 4 per cent on value	120	
Total expense	2,362	2,315
Interest on landlord's capital	2,448	
Labor income of tenant and interest on his capital		2,163
Six per cent interest on working capital	76	194
Interest on real estate, 23.7 per cent	2,372	
Labor income of tenant		1,969

Compared with the average of 90 early-truck farms let for half of the crops, this farm had 17 more acres in truck crops, and its total sales of truck were almost three times as much as the average, exceeding the sales of the average farm by $5,893. The sales of truck crops per acre in truck amounted to $185, as compared with $96 on the average farm. The value of nontruck crops per acre in such crops was more than twice as much as on the average farm. A larger variety of truck crops was grown on this farm than on the average farm. The income from stock was very small.

The expense of the landlord for commercial fertilizer and stable manure ($1,800) for this farm was more than twice as great as on the average farm ($745), and the labor employed other than that of the tenant ($1,630) was about twice as much as on the average farm ($884). This tenant had no family labor to assist him and had to hire all the work he did not do himself. The interest on real estate (23.7 per cent) was high, and the labor income of the tenant ($1,969), while exceeded by that of a few tenants, was more than nine times as great as that received by the average tenant of the group. The landlord lived close to the farm, and both he and the tenant were capable, energetic men.

LATE-TRUCK FARMS LET FOR HALF OF THE CROPS.

On the late-truck farms, as on the early-truck farms let for half of the crops, the tenant furnishes all of the work stock, productive stock, tools, machinery, and labor, the landlord getting half of the sales of truck crops and half of the other crops, but none of the receipts from live stock and live-stock products.

The sales of truck crops are divided equally on all farms. Of the 53 farms growing wheat the landlord received half of the crop on all except one, on which farm he had the entire crop, as he had seeded the wheat before the tenant came on the farm. Field corn was grown on all of the 96 farms of this group, the landlord receiving half of the crop on all of the farms except one, on which the tenant had the entire crop. It is the practice for the tenant to feed all or most of the hay on the farm. From 16 farms the tenant was required to haul a part of the hay crop, in most cases only a few tons, for the landlord's own use. Only two landlords required as a part of the rent as much as one-half of all the hay produced on the farm. Of the 29 farms from which hay was sold the landlord received half of the sales on 28, and on the other farm the tenant had all of the income from hay sold that year, inasmuch as he had brought a quantity of hay to the farm when his tenancy began. Most of the feedable crops produced are used on the farm, but not so large a proportion as on the early-truck farms let for a half of the crops. Of an average total production of nontruck crops, valued at $1,419, there was sold $513 worth, of which $417 worth was sold by the landlord.

On these farms the systems of farming and the soil are such that the production of nontruck crops is much larger than on the farms growing early truck. The question of purchased fertility is also of less importance, so that the landlord is not interested enough to pay for hay or marsh grass which the tenant may find it necessary to purchase. On seven farms the landlord contributed for the purchase of roughage, consisting mostly of marsh grass, an average amount of $19. All other expense for roughage as well as for concentrated feeds on these farms was paid by the tenant.

In Table VII is shown the variation as to practice in the sharing of some of the more important expenses.

TABLE VII.—*Variation in practice as to sharing of expenses on 96 New Jersey late-truck farms rented for half the crops.*

Items of expense.	Number of farms.				
	Having no such expense.	Method of sharing expense.			
		Landlord all.	Half and half.	Tenant all.	Other methods.
Feed and roughage	1			88	Landlord furnishes all roughage on 7 farms.
Seed potatoes (white)	5		91		
Grass and clover seed	9		86	1	
Seed wheat	43	1	51		Tenant 40 per cent, 1 farm.
Fertilizer		1	76		Tenant 33 per cent on 8 farms. Tenant 33 per cent in the row and 50 per cent of other on 1 farm. Tenant 50 per cent in the row only on 9 farms. Tenant 16 per cent, 1 farm.
Manure	75	21			
Packages	6	1	42	46	Tenant 60 per cent, 1 farm.
Spray material	8	1	63	24	
Tool and stock maintenance				96	
Labor				94	Landlord pays a part of the cost of picking, 2 farms.
Real-estate tax		20	69	1	Tenant less than half on 6 farms.
Building maintenance		96			A few minor exceptions.

Purchased stable manure was used on 21 farms at an average cost of $135, all of which was paid by the landlord. Commercial fertilizer was bought on all 96 farms, but some variation was observed in the sharing of its cost. On 76 farms each paid half of the cost of all commercial fertilizer and on the other farms the landlord paid more than half of the cost but on only one farm did he pay the entire cost. On this farm a number of special truck crops were grown.

The landlord, as a rule, paid half the cost of seed, which was chiefly seed white potatoes, for, as on the early-truck farms, it is not the general practice to grow seed potatoes. Tomato and grain seeds are saved each year. The truck crops grown are not such as require starting in hotbeds.

The tenant pays all cost of picking tomatoes for the cannery, which is usually done by the regular help of the farm with but little of the outside piecework that is employed on farms growing early truck. Half of the tenants furnished all of the baskets used for picking and gathering crops, while on almost all of the other farms the landlord paid half of the cost of these baskets. It is unusual for truck crops to be sold in packages from these farms.

Of the 96 tenants, one paid all, 69 paid half, 6 paid less than half, and the other 20 paid none of the real-estate tax.

In Table VIII are given the average amounts of the different items of receipts and expenses on the 96 farms in question.

TABLE VIII.—*Landlord's and tenant's average receipts and expenses on 96 late-truck farms leased for half of the crops.*

	Landlord.	Tenant.
Sources of receipts:		
Nontruck crops sold	$417	$96
Tomatoes	199	199
White potatoes	575	575
Other truck crops	11	11
Poultry and eggs	....	260
Dairy products (10.9 cows)	....	925
Other income from stock	....	77
All other receipts	2	6
Total	1,204	2,149
Items of expense:		
Feed	1	393
Seed	113	115
Commercial fertilizer	247	200
Stable manure	30	....
Packages	4	11
Spray material	7	10
Tool maintenance (estimated at 18 per cent on value)	....	130
Hired labor, board included	1	473
Value of family labor	....	122
Real-estate tax	59	40
Maintenance of buildings (estimated at 4 per cent on value)	99	....
Other expenses	9	79
Total	570	1,573
Interest on landlord's capital	634	....
Labor income of tenant and interest on his capital	....	576
Interest on working capital 6 per cent (landlord $216, tenant $3,256)	13	195
Labor income of tenant	....	381
Interest on real estate, 6.5 per cent on $9,568	621	....
Equivalent cash rent per acre, $7.29.		

In Table IX is summarized the year's business on a late-truck farm let for half of the crops. This farm, by comparison with the average of the 96 farms with which it is included in Table VIII, is much more profitable to both landlord and tenant.

TABLE IX.—*Summary of a year's business on a successful late-truck farm let for half of the crops.*

Acres in farm, 115; value of farm, $15,000; buildings alone, $2,500.
Working capital furnished by tenant, $3,700, consisting of stock (6 work horses, 11 cows, 1 bull, hogs, and poultry) $2,300, machinery and tools $650, feed and supplies $700, cash $50.
Working capital furnished by landloard (feed and supplies), $350.
Acres in pasture, 12.
Acres in nontruck crops, 56 (corn 24, tame hay 12, meadow hay 20).
Value of nontruck crops produced, $1,940; value of nontruck crops per acre, $35.
Acres in truck crops, 43; sales, $3,850; sales per acre in truck, $90.

	Landlord.	Tenant.
Sources of receipts:		
Corn (landlord's half of crop)	$550	....
Cornstalks	15	$15
Hay	50	50
Tomatoes for canning (9 acres)	375	375
White potatoes (34 acres)	1,550	1,550
Income from stock (calves, $50; poultry and eggs, $300; milk, $1,650)	....	2,000
Income from crops and stock	2,540	3,990
Items of expense:		
Feed	....	400
Seed potatoes	200	200
Other seed	16	16
Commercial fertilizer	500	500
Stable manure	20	....
Baskets	....	5
Spray material	37	37

TABLE IX.—*Summary of a year's business on a successful late-truck farm let for half of the crops*—Continued.

	Landlord.	Tenant.
Items of expense—Continued.		
Tool maintenance, estimated at 18 per cent on value		117
Shoeing and veterinary		25
Taxes and insurance on working capital		24
Regular labor, board included		700
Family labor		200
Real-estate tax	62	62
Maintenance of buildings, estimated at 4 per cent on value	100	
Total expense	935	2,286
Interest on landlord's capital	1,605	
Labor income of tenant and interest on his capital		1,704
Six per cent interest on working capital	21	222
Interest on real estate, 10.6 per cent	1,584	
Labor income of tenant		1,482

This farm had 43 acres in truck crops as compared with 22 on the average of 96 late-truck farms let for half of the crops; the acreage of nontruck crops was practically the same as the average, but the value of nontruck crops per acre was greater; the value of truck crops per acre was $90 as compared with $73 on the average farm. The income from stock was $2,000, as compared with $1,262 on the average farm, although the number of cows kept was the same. This farm was more successful than the average, largely because of the greater acreage in truck crops, the greater sales of truck crops per acre in truck, and the greater income from stock.

The cost of feed on this farm was about the same as on the average farm, but the cost of fertilizer was more than twice as much, and because of the larger acreage of white potatoes the cost of seed was greater than on the average farm by $204. Labor other than the tenant's exceeded by $304 that used on the average of these 96 farms. On the value of the real estate, 10.6 per cent was realized. The labor income of the tenant was $1,482, which was exceeded by that of only two other tenants in the group of 96 farms.

FARMS LET FOR HALF OF THE CROPS AND HALF OF THE MILK.

The 12 farms from which the landlord received as rent half of the sales of all crops and half of the income from the dairy are located, in the main, on the heavier soil type, and dairying is an important enterprise. These farms are, on the average, larger and more desirable than the farms growing late truck, which give only half of the crops as rent. The average sales of dairy products on these 12 farms amounted to $2,700, in comparison with $925 from the 96 late-truck farms let for half of the crops.

On the farms of this group the tenant furnished the work stock, tools, machinery, labor, and all the productive stock except the dairy herd, in which he had a half interest. In a few instances the landlord owned a part of the work stock and machinery in addition to half of the dairy herd.

Sales of truck crops were divided equally on all farms growing truck in 1913. The landlord's income from nontruck crops sold was larger than that of the tenant, because the tenant did not in all cases feed the work stock or the hogs and poultry from the undivided crops. The tenant had, however, a larger income from stock and stock products than the landlord, because the receipts from hogs and poultry were not divided. The receipts from milk sold and the increase in the value of the dairy herd were divided equally.

Such little stable manure as was purchased on these farms was paid for by the landlord. The tenant usually paid half of the cost of commercial fertilizer; but the fertilizer used on truck crops other than white potatoes was usually furnished by the landlord.

Half the cost of feed and seed purchased on these farms was paid by the landlord, and on several farms the landlord paid all the cost of grass and alfalfa seed. Early white potatoes are an important truck crop on these farms, so that the cost of seed is considerable.

The tenant as a rule furnished all labor, including that for the picking of tomatoes. One landlord furnished a man to work in the dairy and also a part of the dairy equipment.

In Table X are given the averages of the different items of receipts and expenses on these 12 farms.

TABLE X.—*Landlord's and tenant's average receipts and expenses on 12 New Jersey farms rented for half the sales of crops and half the dairy receipts.*

	Landlord.	Tenant.
Sources of receipts:		
Nontruck crops sold	$361	$259
Tomatoes	135	135
White potatoes	715	715
Sales of other truck crops	15	15
Poultry and eggs	....	246
Dairy products (25.8 cows)	1,350	1,350
Other income from stock	67	169
All other receipts	....	18
Total	2,643	2,907
Items of expense:		
Feed	466	460
Seed	189	122
Commercial fertilizer	361	255
Stable manure	29	6
Packages	5	11
Spray material	10	7
Tool maintenance, estimated at 18 per cent on value	18	142
Hired labor, board included	21	736
Value of family labor	2	82
Real-estate tax	123	22
Maintenance of buildings, estimated at 4 per cent on value	168	....
Other expense	53	109
Total	1,445	1,952
Interest on landlord's capital	1,198	....
Labor income of tenant and interest on his capital	....	955
Interest on working capital at 6 per cent (landlord, $1,924; tenant, $4,008)	115	240
Labor income of tenant	....	715
Interest on real estate (7.7 per cent on $14,125) Equivalent cash rent per acre, $8.95.	1,083	....

In Table XI is summarized the year's business of a farm let for half of the crops and half of the dairy receipts. This farm is considerably more profitable to both landlord and tenant than the average of the 12 farms with which it is grouped in Table X.

TABLE XI.—*Summary of a year's business on a successful farm on which the milk, as well as the crop receipts, were divided.*

Acres in farm, 135; value of farm, $13,000; buildings alone, $5,000.
Working capital furnished by tenant, $5,545, consisting of stock (7 work horses, 15 cows, 5 young cattle, 8 hogs, poultry), $3,245; machinery and tools, $1,200; feed and supplies, $900; cash, $200.
Working capital furnished by landlord, $2,470, consisting of stock (15 cows, 5 young cattle), $1,570; feed and supplies, $900.
Acres in pasture, 9.
Acres in nontruck crops, 85 (field corn 25, silage corn 15, upland hay 25, marsh hay 20); value of nontruck crops produced, $3,052; value of nontruck crops per acre, $36.
Acres in truck crops, 30; sales, $3,354; sales per acre in truck, $112.

	Landlord.	Tenant.
Sources of receipts:		
Corn sold	$175	$175
Upland hay sold	219	219
White potatoes (30 acres)	1,677	1,677
Income from stock	2,376	3,061
Milk, $4,400; calves, $72 (shared equally); hogs, $35; poultry and eggs, $550 (tenant has all); increased value of stock, landlord, $140; tenant, $240.		
Income from stock and crops	4,447	5,132
Items of expense:		
Feed	700	700
Seed potatoes	200	200
Grass seed	50	
Potato fertilizer	360	360
Corn fertilizer (broadcasted)	180	
Baskets	8	8
Bordeaux mixture	40	
Other spray material	8	8
Tool maintenance, estimated at 18 per cent on value		216
Shoeing		30
Veterinary	6	6
Taxes and insurance on working capital	11	28
Hired labor, board included		950
Family labor (none)		
Real-estate tax	150	
Maintenance of buildings, estimated at 4 per cent on value	200	
Total expense	1,913	2,506
Interest on landlord's capital	2,534	
Labor income of tenant and interest on his capital		2,626
Six per cent interest on working capital	148	333
Interest on real estate, 18.3 per cent	2,386	
Labor income of tenant		2,293

This farm had 30 acres of truck crops and 85 acres of nontruck crops, which acreages exceed by 7 and 19 acres, respectively, those of the averages for the 12 farms with which it is grouped in Table X. The value of nontruck crops per acre was slightly greater on this farm than the average of the group, and the sales of truck crops were $112 per acre as compared with $75. The income from stock ($5,437) exceeded by $2,255 that of the average of the group, and was more than four times as great as that for the average of 96 late-truck farms let for half of the crops. This farm was heavily equipped with buildings, which included three silos. The expenses for feed, seed, fertilizer, and labor were greater than for the average of the 12 farms, but the interest on the value of real estate (18.3 per cent) and the labor income of the tanant ($2,386) exceeded that of any other of these farms.

FARMS LET FOR A SHARE OTHER THAN A HALF.

On 13 farms, 4 of which are of the late-truck and 9 of the early-truck type, the rent was a share other than a half. Many of the men owning these farms lived on or near them. They did not find it desirable to farm the land personally and, finding it possible to obtain labor for a share of the product in lieu of wages, adopted this method of operating their farms. Their tenants usually occupied a position intermediate between that of a hired laborer and that of a tenant operating independently of the landlord's working capital. Without sufficient capital of their own to operate a farm, these tenants were unable to secure the same terms that tenants with sufficient capital could get. Some of the landlords letting to such tenants had to purchase the stock and tools necessary to supplement that which the tenant was able to furnish, and others who had farmed the land themselves or let their farms under similar conditions previously, already had the necessary working capital.

Eight of these 13 farms were leased under a two-thirds system, by which the tenant furnishes the labor for one-third of the crops. The landlord furnished the work stock, tools, and machinery, commercial fertilizer and stable manure, feed for the work stock, and met the cost of tool maintenance and most of the other general expenses. The landlord personally assisted on some of the farms and, in one case, paid for all the hired picking labor. On several farms the tenant had to meet a third of the cost of packages, but he was at little other expense, except that if he furnished any tools or stock he kept such tools in repair, and furnished the feed for his stock. On most farms of this group the landlord reserved all of the nontruck crops, unless the tenant had some stock, in which case he was allowed the use of the farm roughage and, in some cases, a third of the non-truck crops.

In Table XII are given the averages of the different items of receipts and expenses on the 13 farms let for a share other than a half.

TABLE XII.—*Landlord's and tenant's average receipts and expenses on 13 New Jersey tenant farms rented for a share other than a half.*

	Landlord.	Tenant.
Sources of receipts:		
Nontruck crops sold	$127	$75
Truck crops sold	1,488	893
Income from stock	171	155
Other receipts		1
Total	1,786	1,124
Items of expense:		
Feed	84	34
Seed	111	9
Commercial fertilizer	336	18
Stable manure	169	
Packages	64	13
Spray material	15	1
Tool maintenance, 18 per cent on value ($377 and $133)	68	24
Sash maintenance, 10 per cent on value ($135 and $18)	14	2
Hired labor, board included	84	480
Family labor	31	19
Real-estate tax	75	2
Maintenance of buildings, 4 per cent on value, $1,992	80	
Other expenses	32	19
Total	1,163	621
Interest on landlord's capital	623	
Labor income of tenant and interest on his capital		503
Interest on working capital at 6 per cent (landlord, $1,722; tenant, $766)	103	46
Labor income of tenant		457
Interest on real estate, 6.6 per cent on $7,838	520	
Equivalent cash rent per acre, $7.43.		

CASH RENTING.

On farms let for a cash rent the tenant furnishes everything except the land and buildings. The farms are, on the average, smaller and less valuable than farms let for a share. The average rent paid per acre is less than that which landlords receive who let their land for a share of the crops. This is to be expected because these farms are less desirable and because the landlord letting for a cash rent does not take the risk entailed by variation in season and market, nor does he risk losing an investment made in fertilizer and manure as do landlords who let for a share. The equivalent cash rent per acre on 22 cash rented farms raising early truck was $3.65 as compared with an equivalent of $6.88 on 90 early-truck farms let for half of the crops. The equivalent cash rent per acre on 13 cash rented farms raising late truck was $5.25 as compared with an equivalent of $7.29 on 96 late-truck farms let for half of the crops.

The cash rent is usually paid in two installments per year. No set time for the payments is generally recognized, but it is usual to make the first payment as soon as some of the crops can be sold. On some farms the rent is payable all or part in advance. Some tenants paid a certain stated cash rent and the real-estate taxes in addition, and one paid a stated rent and taxes and also maintained the buildings and fences in good condition.

In Table XIII are given the average amounts of the different items of receipts and expenses on the 35 farms leased for a cash rent.

TABLE XIII.—*Landlord's and tenant's average receipts and expenses on 35 cash rented New Jersey truck farms.*

	22 early-truck farms.		13 late-truck farms.	
	Landlord.	Tenant.	Landlord.	Tenant.
Sources of receipts:				
Nontruck crops sold		$40		$172
Tomatoes		758		170
Sweet potatoes		533		
White potatoes		87		836
Other truck sales		371		
Poultry and eggs		111		179
Dairy products		[1] 310		[2] 889
Other income from stock		4		93
Cash rent	$274		$413	
All other receipts	2	46		4
Total	276	2,260	413	2,343
Items of expense:				
Feed		253		316
Seed		50		176
Fertilizer and manure	9	466	3	368
Packages		81		11
Spray material		17		24
Tool maintenance, 18 per cent on value ($473 and $577)		85		104
Sash maintenance, 10 per cent on value ($172)		17		
Hired labor, board included		433		308
Value of family labor		156		162
Real-estate tax	47	5	40	36
Maintenance of buildings, 4 per cent on value	53	2	73	10
Cash rent		274		413
Other expense	9	51		79
Total	118	1,890	116	2,007
Interest on landlord's capital	158		297	
Labor income of tenant and interest on his capital		370		336
Interest on working capital at 6 per cent ($2,263 and $2,990)		136		179
Labor income of tenant		234		157
Interest on real estate	158		297	
Equivalent cash rent per acre	3.65		5.25	

[1] 3 cows. [2] 9.9 cows.

VARIATION IN INCOMES.

The average labor income of 246 tenants was $332. Of six tenants making a labor income of over $2,000, four were tenants growing early truck and giving half of the crops as rent, one was a tenant giving half of the crops and dairy receipts, and one was a cash renter. Of the 246 tenants, 59 per cent made a labor income between $0 and $1,000 and 29 per cent failed to make a labor income. The labor income of tenants on farms on which early truck is grown is subject to greater variation than on farms on which late truck is grown. On the former group of farms, 53 per cent of the tenants made labor incomes between $0 and $1,000, whereas 67 per cent of the tenants in the latter group made labor incomes between the same limits.

TABLE XIV.—*Variation in the size of the labor income of tenants on 246 New Jersey truck farms.*

Labor income of tenant.	Total number.	Number in each tenure group.					
		Half of crops.		Half of crops and of milk.	Share other than half.	Cash rent.	
		Early truck.	Late truck.	Late truck.	Either early or late truck.	Early truck.	Late truck.
Over $1,500	13	6	3	2	....	1	1
$1,000 to $1,500	15	3	8	2	1	1	....
$500 to $1,000	56	19	26	2	3	4	2
$0 to $500	90	29	38	4	8	6	5
Minus $500 to $0	56	23	18	2	1	8	4
Less than minus $500	16	10	3	....	....	2	1
All farms	246	90	96	12	13	22	13

The income available to the family of the tenant is also of significance for purposes of comparison. If we add to the labor income of the tenant the value of unpaid family labor and 6 per cent on his investment in working capital, both of which are deducted from the receipts of the tenant in obtaining his labor income, we have the amount available to the tenant and his family for living expenses and from which to save, assuming that the tenant does not have any interest to pay on borrowed capital. The average family income of 246 tenants was $633. Table XV shows the variation in the size of the family income.

TABLE XV.—*Variation in the size of the family incomes of the families of 246 tenants on New Jersey truck farms.*

Tenant's family income.	Total number.	Number of farms in each tenure group.					
		Half of crops.		Half of crops and of milk.	Share other than half.	Cash rent.	
		Early truck.	Late truck.	Late truck.	Either early or late truck.	Early truck.	Late truck.
Over $1,500	25	8	9	4	....	2	2
$1,000 to $1,500	28	10	13	....	2	2	1
$500 to $1,000	78	28	35	4	3	5	3
$0 to $500	83	27	33	4	7	8	4
Minus	32	17	6	....	1	5	3
All farms	246	90	96	12	13	22	13

Thirteen per cent of the 246 tenants failed to make any family income. In other words, when allowances are made for all expenses and for the maintenance of the working capital, these tenants, their families, and their capital were employed a year without reward. Sixty-five per cent of the 246 tenants made a family income of between

$0 and $1,000. There were more who made over $1,000 than there were who failed to make any family income.

The owners of the 246 farms realized on the investment in real estate an average of 6.6 per cent. Sixteen landlords made over 15 per cent on their investment in real estate, and of these 13 were owners of early-truck farms let for half of the crops, one of a farm let for a half of the crops and of milk receipts, and two of farms let for a share other than a half.

In Table XVI is shown the variation in the interest realized on the value of real estate by the owners of 246 New Jersey tenant truck farms.

TABLE XVI.—*Variation in interest on value of real estate realized by landlords of 246 New Jersey tenant truck farms.*

Landlord's interest on investment in real estate.	Total number.	Number in each tenure group.					
		Half of crops.		Half of crops and of milk.	Share other than half.	Cash rent.	
		Early truck.	Late truck.	Late truck.	Either early or late truck.	Early truck.	Late truck.
Over 15 per cent	16	13	....	1	2	....	....
10 per cent to 15 per cent	31	18	11	1	1	....	....
5 per cent to 10 per cent	102	21	56	8	6	6	5
0 per cent to 5 per cent	76	25	26	2	2	14	7
Less than 0 per cent	21	13	3	....	2	2	1
All farms	246	90	96	12	13	22	13

The greatest range of interest realized on investment in real estate is shown in the group of farms growing early truck and let for half of the crops. The great variation in this group is partly explained by the large expense for fertilizer and manure, amounting on the average to $722, which expense is not always compensated by a corresponding income from the crops produced. Comparative stability in respect to the interest realized on real estate is shown by the group of 96 farms growing late truck and let for half of the crops, 58 per cent of the landlords in this group receiving between 5 and 10 per cent. Sixty per cent of the landlords renting their farms for cash realized an income on their investment in real estate of between 0 and 5 per cent.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 412

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APER September 22, 1916

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given in Table I, represent the experience of several hundred practical farmers in western New York, and has application to the conditions which existed there. Knowledge of what is accomplished by farmers in other localities is also of value to those in western New York, because for more operations other sections of the United States have worked out more efficient methods of doing work and handling men,

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TABLE XVI.—*Variation in interest on value of real estate realized by landlords of 246 New Jersey tenant truck farms.*

Landlord's interest on investment in real estate.	Total number.	Number in each tenure group.					
		Half of crops.		Half of crops and of milk.	Share other than half.	Cash rent.	
		Early truck.	Late truck.	Late truck.	Either early or late truck.	Early truck.	Late truck.
Over 15 per cent	16	13		1	2		
10 per cent to 15 per cent	31	18	11	1	1		
5 per cent to 10 per cent	102	21	56	8	6	6	5
0 per cent to 5 per cent	76	25	26	2	2	14	7
Less than 0 per cent	21	13	3		2	2	1
All farms	246	90	96	12	13	22	13

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 412

OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. PROFESSIONAL PAPER September 22, 1916

THE NORMAL DAY'S WORK OF FARM IMPLEMENTS, WORKMEN, AND CREWS IN WESTERN NEW YORK.

By H. H. Mowry, *Agriculturist.*

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Every farmer needs to have a definite idea as to what constitutes a fair day's work in each of his operations, so that the annual work may be planned intelligently and carried out on time. In order to obtain results from hired help it is necessary to know what each man and team should accomplish daily. The same knowledge will serve to prevent the overtaxing of horses and the crowding of men beyond a fair amount of service. Where hired help understand that a fair and definite amount of work, not in excess of what can be performed day after day without impairing health or efficiency, is normally expected, the necessity of personal supervision by the employer is reduced. Compensation can also be asked and paid on the basis of this reasonable service and the relations of all concerned be made more satisfactory.

Knowledge of what constitutes a fair day's work in a given locality,
bors, is a valuable guide to the
lletin, a summary of which is
e of several hundred practical
application to the conditions
at is accomplished by farmers
those in western New York,
ons of the United States have
loing work and handling men,

horses, and implements than those in vogue in this section. Hence, in discussing the various operations in the following pages, comparisons are made between what farmers in New York accomplish and the average for the entire United States.

A NORMAL DAY'S WORK.

In the following summary table is shown the mean daily duty of implements, workmen, and crews for various farm operations, averages for western New York, as determined by this investigation, being compared with averages for the entire United States, as determined by a previous survey.[1] In making these comparisons those sizes of implements and crews were taken which are most generally used and for which the largest numbers were reported.

TABLE I.—*Summary and comparisons.*

Operation.	Daily duty.	
	Western New York average.	United States average.[1]
Walking plow:	*Acres.*	*Acres.*
2 horses, 12-inch	1.65	1.76
3 horses, 14-inch	1.78	2.32
Sulky plow, 3 horses, 14-inch	2.20	2.40
Spike-tooth harrow:		
2 horses, 8-foot	13.0	10.8
3 horses, 10-foot	17.3	15.3
Spring-tooth harrow:		
2 horses, 6-foot	9.0	7.4
3 horses, 6-foot	10.2	8.2
4 horses, 8-foot	14.7	13.1
Disk harrow, fresh plowed land:		
2 horses, 6-foot	7.5	7.2
3 horses, 6-foot	8.2	7.5
4 horses, 8-foot	11.1	12.8
Land roller, 2 horses, 8-foot	13.8	13.2
Grain drill, 2 horses, 6-foot	10.0	8.8
Grain binder, 3 horses, 6-foot	10.4	11.1
Setting up bound grain, 1 man	7.5	9.3
Planting corn:		
Hand planter, 1 man	3.4	4.4
1-horse, 1-row	5.2	6.9
2-horse, 2-row	10.7	13.6
Cultivating:		
1-horse	4.1	4.4
2-horse	6.8	6.6
Cutting corn by hand, 1 man, yield 41-60 bushels	1.1	1.5
	Acres.	*Acres.*
Setting up corn after corn binder, 1 man	3.4	4.0
Corn binder:		
2 horses	5.3	6.6
3 horses	5.7	7.3
Mowing hay (5-foot cut)	9.0	8.9
Raking hay (10 feet wide):		
1 horse	15.0	16.3
2 horses	17.6	17.9
Tedding hay, 2 horses	14.3	14.5
Cocking hay, 1 man	6.3	6.3
Hauling hay from field to barn, 2 men and 2 horses:		
Unloading by hand	4.9	4.4
Unloading with sling	6.6	6.1
Picking apples:	*Bushels.*	*Bushels.*
Yield 1 to 10 bushels	52.3	34.0
Yield over 10 bushels	70.0	44.8
Husking corn from shock, 1 man	32.2	45.9
Threshing wheat from shock, 10 men and 6 horses	715.3 *Acres.* 25.1	679.0 *Acres.* 29.5
Hauling manure with spreader	*Loads.* 14.7	*Loads.* 13.1

[1] U. S. Department of Agriculture Bulletin No. 3.

SOURCE OF DATA.

The information made available in this bulletin was obtained from farmers in Wayne, Ontario, Monroe, Genesee, Livingston, Orleans, and Niagara Counties. A circular of inquiry afforded an opportunity for experienced farmers to record their knowledge as to what constitutes a fair day's work under their conditions, and these records were averaged and assembled in the tables which follow.

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[1] U. S. Department of Agriculture Bulletin No. 3.

LOCAL CONDITIONS.

Farm land in the section where these data were obtained is somewhat rolling, but not to an extent to reduce appreciably the average amount of work that can be done daily. Some of the heavier soils of the Dunkirk series can not be plowed as rapidly as can the more loamy soils of the Middle West. The presence of more or less stone throughout the section also operates to reduce the amount of work that can be done daily with plows. There are no local reasons why farm implements that are drawn over the land, like mowers, binders, rakes, etc., should not perform as much work daily here as anywhere. The horses used in western New York average 1,211 pounds in weight. The average net day in the field in spring and summer work was found to be 9 hours and 38 minutes, and in haying and harvest it is 9 hours and 49 minutes. This net day excludes the time going and coming and the noon period, and represents only the time in action on the various operations.

PLOWING.

Table II gives the average performance of the walking plow with 2-horse and 3-horse teams working on sod and on stubble. From 10 to 15 per cent more land can be plowed in stubble than on sod where only two horses are used. With 3-horse teams, there is little difference between the work on sod and on stubble. Breaking sod is work that is too heavy for two horses. With two horses, the depth plowed ranges from 6 to 6½ inches on stubble and is 6 inches on sod. With three horses, the plowing on sod ranges from 6½ to 7¼ inches deep and on stubble from 7 to 7½ inches deep. The majority of farmers use three horses when breaking sod and two horses when plowing stubble. The 3-horse teams permit the use of wider plows and deeper plowing. The farmers in western New York accomplish only about 80 to 85 per cent as much daily in their plowing work as does the average farmer in the United States. This is doubtless due to the heavy character of the local soils.

TABLE II.—*A fair day's work for walking plows with 2-horse and 3-horse teams on sod and on stubble.*

Horses.	Width.	On sod.		On stubble.	
		Acres.	Number of farms averaged.	Acres.	Number of farms averaged.
	Inches.				
2	10	1.46	124	1.66	220
2	12	1.47	217	1.65	315
2	14	1.48	111	1.72	135
3	10	1.70	86	1.82	52
3	12	1.74	225	1.85	146
3	14	1.78	198	1.93	140
3	16	1.90	45	1.95	15

In Table III is shown the duty of sulky plows in western New York working on sod and on stubble. Few New York farmers attempt to operate sulky plows with two horses. The load is entirely too great for two horses, and only poor plowing can be done with less than three horses. The 14-inch plow is most commonly used on the sulky in this section, while the 16-inch is the most common for the average of all farmers in the country. In the soils of New York the 14-inch sulky is an ample load for three horses. From 5 to 10 per cent more work can be done on stubble than on sod with the sulky plow.

TABLE III.—*A fair day's work for sulky plows drawn by three horses on sod and on stubble.*

Horses.	Width.	On sod.		On stubble.	
		Acres.	Number averaged.	Acres.	Number averaged.
	Inches.				
3	12	1.95	86	2.11	86
3	14	2.08	105	2.20	115
3	16	2.26	51	2.37	42

HARROWING.

The spike-tooth or smoothing harrow can be operated with 2-horse or 3-horse teams in a wide range of widths, as it is an implement of comparatively light draft. Three horses accomplish from 10 to 15 per cent more work on the same width of harrow than two horses do. Table IV gives the average duty for the spike-tooth harrow for widths ranging from 5 to 12 feet for 2-horse and 3-horse teams.

TABLE IV.—*A fair day's work for the spike-tooth harrow with 2-horse and 3-horse teams.*

Width.	2-horse teams.		3-horse teams.	
	Acres.	Number. averaged.	Acres.	Number averaged.
Feet.				
5	11.2	15	11.0	2
6	11.1	87	11.9	27
7	12.0	102	13.2	33
8	13.0	199	14.1	75
9	13.8	43	16.4	48
10	16.1	102	17.3	80
12	14.8	20	19.1	38

Where two horses are required to draw widths greater than 10 feet they appear to be overloaded so that their daily efficiency is reduced.

The spring-tooth harrow is used to do the hard, preliminary work of fitting the land after plowing. It is adapted to soils which are too hard, stony, lumpy, or so occupied with stumps as to render the spike-tooth or disk harrow ineffective. On account of its heavy draft it can not be used in such extreme widths as can the spike-tooth harrow. Three horses are more suitable than two on even the narrowest widths, while a 4-horse team finds an 8-foot or 9-foot spring-tooth harrow a heavy load.

TABLE V.—*A fair day's work for spring-tooth harrows with teams of two, three, and four horses.*

Width.	2-horse teams.		3-horse teams.		4-horse teams.	
	Acres.	Number averaged.	Acres.	Number averaged.	Acres.	Number averaged.
Feet.						
6	9.0	36	10.2	33	....	....
7	9.3	6	10.9	21	....	....
8	9.7	7	13.3	10	14.7	3
9	....	....	....	....	18.0	8

In Table VI is shown the daily averages for the disk harrow with 2-horse, 3-horse, and 4-horse teams working on fresh-plowed and on well-packed land, respectively. It appears that with two and three horses, increasing the width of the disk harrow does not result in any great increase in acreage disked. This is more true on fresh-plowed than on well-packed land. Where four horses are used, increasing the width results in more marked increases in daily accomplishment. The heavy draft of the disk harrow accounts for the lack of increase in results with increasing width where 2-horse and 3-horse teams are used. The implement is an overload, as a rule, for anything less than four horses; so that any increase in width with the smaller units of power results in less speed and mileage per day.

TABLE VI.—*A fair day's work for disk harrows using teams of two, three, and four horses, respectively.*

Horses.	Width.	On fresh-plowed land.		On well-packed land.	
		Acres.	Number averaged.	Acres.	Number averaged.
	Feet.				
2	5	7.1	60	8.4	61
2	6	7.5	152	9.1	149
2	7	7.8	44	9.6	44
2	8	7.8	38	10.0	38
3	5	8.1	44	9.4	44
3	6	8.2	205	9.8	201
3	7	8.1	90	9.9	89
3	8	8.8	48	10.3	49
4	6	7.6	16	9.1	155
4	7	9.8	15	12.2	15
4	8	11.1	25	13.3	25

THE LAND ROLLER.

The land roller (Table VII) is an implement of relatively light draft, and two horses operate a wide range of width. Its limit in width is determined by the awkwardness of the larger sizes rather than by their draft. The table shows an increasing acreage with increasing width, although the increase in results is not in proportion to the increase in width.

TABLE VII.—*A fair day's work for the land roller drawn by two horses.*

Width.	Acres.	Number averaged.
Feet.		
6	11.4	76
7	12.5	255
8	13.8	588
9	14.0	117
10	14.6	136
12	15.3	23

GRAIN CROP OPERATIONS.

From Table VIII it is seen that nearly all farmers in western New York use a grain drill sowing 11 rows, or a strip from 6 to 6½ feet wide. With this size drill the grain and grass can be sown regularly, and in addition corn can be drilled two rows at a time, 42 inches apart, or three rows at a trip, 35 inches apart. Beans can also be drilled 28 inches apart, sowing three rows at each trip. The daily acreage planted for drills having 9, 10, and 11 tubes is shown in the table.

TABLE VIII.—*A fair day's work for grain drills drawn by two horses.*

Number of drill rows.	Acres.	Number averaged.
9	9.2	95
10	9.6	67
11	10.0	951

Table IX gives the duty of the grain binder in western New York. Four-horse teams are seldom used in this section, and the smaller widths are often drawn by two horses. The 6-foot binder and three horses are most commonly used. The 7-foot binder is too heavy for three horses.

TABLE IX.—*A fair day's work with the grain binder in western New York, using 2-horse and 3-horse teams.*

Horses.	Width.	Acres.	Number averaged.
	Feet.		
2	5	7.6	16
2	6	9.3	71
3	5	9.6	73
3	6	10.4	901
3	7	11.3	83

In Table X is shown the average acres of grain that can be set up in shocks by one man after a grain binder. The bulk of the straw influences the daily acreage to some extent.

Table X.—*A fair day's work for a man setting up grain in shocks after the grain binder.*

Yield.		Acres.	Number averaged.
Straw.	Grain.		
Tons.	*Bushels.*		
1.3	20	7.7	278
1.4	25	7.6	380
1.6	30	7.4	313
1.7	35	7.3	25

THRESHING WHEAT.

The amount of grain threshed daily is determined by the yield of the crop more than by any other condition. Table XI gives the daily duty of average crews in threshing wheat from shock in western New York. About 25 acres is a fair day's work, irrespective of yield, in threshing from shock.

Table XI.—*Threshing wheat from shock—A fair day's work with average crews.*

Yield.	Crew.		Bushels daily.	Acres daily.	Number averaged.
	Men.	Horses.			
Bushels.					
0–20..........	8 or 9	4 or 6	561.7	24.3	124
21–30..........	9 or 10	6	715.3	25.1	244
31 and over...	10 or 11	4 or 6	909.8	25.3	22

Table XII gives the duty of average crews in threshing from stack or in barn, both for wheat and for oats. The yield here is the controlling element in the daily output. The crews reported ranged from 5 to 18 men. In this operation, scarcity of help makes it necessary at times to operate with too small a crew, while at other times, where the neighbors help each other, more men are available than are needed. A crew of 8 or 10 men should be ample if the grain is stacked or stored so as to be convenient to the machine.

Table XII.—*Threshing wheat and oats from stack or barn—Normal output of average crews.*

Crew.		Wheat.		Oats.		Number averaged.
Men.	Horses.	Yield.	Bushels.	Yield.	Bushels.	
8 or 9	2 or 4	20	733	35	1,096	97
9 or 10	2 or 4	25	855	45	1,269	107
9 or 10	2 or 4	30	914	55	1,340	124

HANDLING MANURE.

Table XIII shows the normal accomplishment to be expected from a manure spreader operated by one man and using 2-horse and 3-horse teams, respectively. The great majority of farmers find three horses necessary for the operation of a spreader. The advantage of the spreader is realized in more even distribution of manure over the field, in the shorter time required to unload, and in the greater ease of doing the unloading by horsepower than by man power. It takes about two and one-half times as long to unload by hand as with the spreader. There is no advantage in favor of the spreader in the matter of loading.

Manure carriers running on overhead tracks in the barn have largely reduced the laborious work of removing manure from farm buildings, while the spreader has transferred the work of spreading from man to horse. No mechanical device, designed to load manure from the yard to the wagon or spreader, has yet found general adoption on farms. Farmers can eliminate the work of handling manure from barnyards by providing a low-wheeled, low-priced wagon into which the manure from the barn carrier can be emptied as it comes from the stable. The manure spreader can also be set outside, so as to receive the contents of the carrier. By hauling the loaded wagon or spreader to the field as soon as filled, there need be no accumulation of manure in the barnyard, the most laborious operation of loading from the ground by hand is eliminated, the manure is handled and lifted but once into the carrier, and goes directly to the field with a minimum of loss by leaching.

TABLE XIII.—*A fair day's work in handling manure with a manure spreader drawn by two and three horses respectively.*

Horses.	Rods hauled.	Pounds in load.	Loads hauled.	Acres covered.	Number averaged.
2	61.2	2,317	14.5	1.7	123
3	70.4	2,689	14.7	1.8	355

OPERATIONS ON THE CORN CROP.

Table XIV gives the normal efficiency of hand planters, 1-row and 2-row planters, and the grain drill in planting corn. The hand planter is about 60 per cent as efficient as the 1-horse planter, one-third as efficient as the 2-row planter, and one-fourth as rapid as the grain drill. Corn is planted with the grain drill in this section more generally than with the special planters.

TABLE XIV.—*A fair day's work with the implements used in planting corn.*

Implement.	Width of rows.	Acres daily.	Number averaged.
	Inches.		
Hand planter	36	2.9	74
	42	3.4	113
One row, 1-horse planter	36	4.6	62
	42	5.2	93
Two rows, 2-horse planter	36	9.1	84
	42	10.7	124
Grain drill, 2 horses	36	11.3	192
	42	11.6	533

Table XV indicates that the 2-horse walking cultivator is about 50 per cent more efficient than the 1-horse cultivator, and the 2-horse riding cultivator is about 75 per cent more efficient than the 1-horse type. The 1-horse walking cultivator is being displaced by the 2-horse riding type, since the extra horse on the latter is more economical of man time.

TABLE XV.—*A fair day's work in cultivating corn.*

Horses used.	Type of cultivator.	Acres cultivated daily.	Number averaged.
1	Walking	4.1	1,077
2	do	6.2	560
2	Riding	7.1	1,133

In Table XVI the average acreage of corn cut by one man working with a corn knife is shown for increasing yields in terms of ears per acre. About one acre is a good day's work where the yield is over 80 bushels, and one and one-third acres can be cut where the yield is less than 40 bushels. The averages for western New York for this operation are about 25 per cent less than the normal for the United States, the yield being the same. This may be accounted for in part by the fact that corn in New York is planted in drills instead of in hills, requiring more blows of the knife to cut a given number of stalks; also because a short-handled sickle is used in the East which requires much stooping, while a long straight-bladed knife is used in the West, which permits the work to be done while standing practically erect.

TABLE XVI.—*A fair day's work for one man in cutting corn by hand.*

Range of yield (bushels of ears).[1]	Acres cut daily.	Number averaged.
Under 40	1.3	47
41–60	1.2	187
61–80	1.1	402
81 and over	1.1	580

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[1] In Tables XVI, XVII, and XIX the yield of corn is expressed in bushels of ears, this being the customary method of reckoning corn yields in western New York. To convert to bushels of shelled corn divide by 2.

Where corn has been cut by a corn binder, a man's efficiency in setting it up into shocks is multiplied by 3 over what he can accomplish in cutting and setting up by hand. Table XVII gives the daily duty with increasing yields, there being a slight falling off as the yield per acre becomes heavier.

TABLE XVII.—*A fair day's work for a man setting up corn after the corn binder.*

Yield per acre (bushels of ears).	Acres per day.	Number averaged.
50	3.5	102
75	3.4	165
100	3.3	474

From Table XVIII it appears that a very large proportion of farmers use three horses on the corn binder. The amount accomplished daily is about 20 per cent less than the average for the United States. The heavier average yields of corn in New York, as compared with the general average, in part account for this, corn not being grown so extensively here as elsewhere, but more intensively.

TABLE XVIII.—*A fair day's work with the corn binder drawn by two and three horses respectively.*

Horses.	Acres cut daily.	Number averaged.
2	5.3	190
3	5.7	1,001

In husking corn from the shock in western New York, one man averages only from 65 to 75 per cent of the average for the United States, about 35 bushels per day being the normal amount husked in this section. Table XIX gives the average bushels per day and acreage per day for the yields indicated.

TABLE XIX.—*A fair day's work for a man in husking corn from shock.*

Range of yield (bushels of ears).	Acres per day.	Bushels per day.	Number averaged.
Under 41	0.66	36.3	26
41-60	.62	32.2	122
61-80	.47	32.6	293
81 and over	.40	36.0	431

OPERATIONS ON THE BEAN CROP.

In Table XX the average daily work that should be accomplished in some of the field operations with the bean crop are shown. The beans are planted with a grain drill, cultivated with the ordinary cultivators, and harvested with a bean harvester, an implement drawn by two horses and having two long knives, each of which cuts a row, the two rows being thrown in the center between the rows. The beans are then thrown into small piles with a pitchfork, and from time to time the piles are forked and turned over, so that the pods will dry out and cure suitably for threshing.

TABLE XX.—*A fair day's work for the operations in bean growing.*

Operation.	Horses.	Men.	Acres daily.	Number averaged.
Planting with grain drill	2	1	10.9	1,040
Harvesting with bean harvester	2	1	7.6	982
Bunching with fork	....	1	2.8	793
Forking with fork	....	1	2.7	819

In Table XXI the acreage that can be cleared in a day in hauling in the bean crop is shown for the crews commonly used in this section. Doubling the crew does not quite double the acreage cleared daily. Crews larger than two or three men are not very common, since the system of farming is such that the field work can be chiefly done with one regular hired man and members of the family.

TABLE XXI.—*A fair day's work for crews in hauling beans from field to barn.*

Crews.			Acres cleared daily.	Number averaged.
Men.	Horses.	Wagons.		
2	2	1	5.5	459
3	2	1	6.5	355
4	4	2	10.3	64
5	4	2	10.9	35
6	4	2	12.2	17

HAYING OPERATIONS.

In Table XXII is shown the daily duty of men and implements in the haying operations preparatory to hauling into the barn or stacking. The averages for mowing, raking, tedding, and cocking are substantially the same as the averages for the United States as a whole.

TABLE XXII.—*A fair day's work for implements, men, and teams used in making hay.*

Operation.	Men.	Horses.	Width.	Acres daily.	Number averaged.
			Feet.		
Mowing	1	2	4½	8.3	32
			5	9.0	974
			6	10.2	195
Raking	1	1	10	15.0	175
		2	10	17.6	424
Bunching	1	1	10	13.1	89
		2	10	16.3	164
Tedding	1	2	....	14.3	658
Cocking	1	....	....	6.3	1,044

Table XXIII gives the daily duty of the crews ordinarily used in western New York in hauling in hay from the field and unloading by hand. In this section, which is not an extensive haying region, one team only is used in a large majority of cases. Increasing the crew does not result in increasing the amount done in the same proportion, and odd men are the least valuable additions to the crew.

TABLE XXIII.—*A fair day's work with crews used in hauling hay from field to barn and unloading by hand.*

Crews.			Tons daily.	Acres daily.	Number averaged.
Men.	Horses.	Wagons.			
2	2	1	7.7	4.9	342
3	2	1	8.8	5.3	509
3	4	2	10.0	5.6	11
4	4	2	13.3	7.7	50
5	4	2	14.8	8.7	65

In Table XXIV is shown the normal duty of crews in hauling in hay where the unloading is done with the hay sling, or hay fork. Unloading with this inexpensive device increases the efficiency per day about 45 per cent. The farmers in this section are, on the average, from 5 to 10 per cent more efficient in hauling in their hay than the average farmer of the country. The efficiency of the crews shown in Tables XXIII and XXIV can be increased about 10 per cent by the use of the hay loader in the field. Where stacking is done in the field, or where the hay field is within 60 rods of the barn, hay can be put away about 75 per cent more rapidly with the western sweep rakes than with wagons and racks.

TABLE XXIV.—*A fair day's work for crews hauling hay from field to barn and unloading with hay sling or fork.*

Crews.			Tons daily.	Acres daily.	Number averaged.
Men.	Horses.	Wagons.			
2	2	1	10.7	6.6	290
3	2	1	12.6	7.5	496
3	4	2	14.9	9.3	9
4	4	2	17.5	9.8	58
5	4	2	20.1	11.7	82

OPERATIONS ON THE CABBAGE CROP.

In Table XXV the averages for planting cabbage with a transplanter have been brought together for increasing sizes of crews. In all cases there are three men on the transplanter, the additional men and horses being used to bring the plants and water to convenient points for the transplanter. The efficiency per day is not greatly increased by additional men, two men and two horses adding only half an acre, or about 15 per cent to the amount done daily. Two additional men and an extra team are used more frequently, however, than are smaller numbers, these being sufficient when properly directed to keep the transplanter constantly at work.

TABLE XXV.—*A fair day's work in setting cabbage, using three men on the transplanter and additional men and horses as indicated.*

Extra men.	Extra horses.	Acres planted daily.	Number averaged.
....	....	3.4	53
1	....	3.4	42
2	....	3.5	65
1	1	3.5	47
2	1	3.7	83
1	2	3.8	30
2	2	4.0	155

Table XXVI shows the average number of loads and tons of cabbage that can be harvested daily and unloaded on the farm. The smaller crews are most frequently used. The larger crews do not accomplish results in proportion to their size. Two men and two horses and four men and four horses are the most efficient per man and per horse.

TABLE XXVI.—*A fair day's work for crews harvesting cabbage and sorting in the barn.*

Crews.			Loads daily.	Tons daily.	Number averaged.
Men.	Horses.	Wagons.			
2	2	1	7.4	9.8	142
3	2	1	8.0	11.4	107
4	2	1	9.4	13.5	50
4	4	2	12.3	16.4	48
6	4	2	14.9	20.7	16

Where the cabbage is hauled directly from the field to market, the number of loads that can be handled daily with the respective crews is as shown in Table XXVII. On account of its great weight and bulk, cabbage is not grown to any considerable extent on farms over 5 or 6 miles from market, the greater part of this crop being produced on farms that are from 2 to 4 miles from shipping point.

TABLE XXVII.—*A fair day's work for crews harvesting cabbage and hauling directly to market—loads per day.*

Crews.			Miles to Market.									
			1		2		3		4		5	
Men.	Horses.	Wagons.	Loads.	Number averaged.	Loads.	Number averaged.	Loads.	Number averaged.	Loads.	Number averaged.	Loads.	Number averaged.
2	2	1	5.1	*13*	3.9	*51*	3.1	*29*	2.5	*23*	2.5	*13*
3	2	1	5.8	*17*	4.6	*30*	3.5	*16*	3.5	*12*	2.4	*5*
4	2	1	4.7	*3*	4.7	*16*	3.6	*18*	3.5	*3*	3.6	*5*
4	4	2	10.4	*5*	6.9	*15*	6.0	*10*	4.7	*5*	4.0	*1*
6	4	2	11.3	*3*	7.0	*2*	6.5	*4*	7.0	*2*	4.1	*1*

OPERATIONS ON FRUIT CROPS.

The data for Tables XXVIII to XXXIII were obtained in western New York under conditions where orcharding is on a commercial basis and the work is well standardized. They refer to well-established orchards and the customary methods and practice which obtain among the vast majority of growers. Baldwins and Greenings predominate among the orchards and the data presented refer to trees having their general habits of growth. Trees are pruned quite regularly, few, if any, neglected orchard conditions and abnormal factors being incorporated in the averages. Fruit growers in this region necessarily know quite definitely what an average day's work should be for the various orchard operations.

In Table XXVIII are given the averages for pruning fruit trees and for thinning the fruit from apple trees where the crop is too heavy to permit the maturing of good fruit. In general, the thinning operation does not present a serious labor problem except on occasional years when a very heavy crop is set. At other times wind and storm are likely to remove even more than the excess and fruit is not thinned on that account. The data for thinning refers to the average tree in the orchard in years when thinning is necessary.

TABLE XXVIII.—*A fair day's work in pruning fruit trees and in thinning the fruit from apple trees.*

Operation.	Trees daily.	Number averaged.
Pruning apple trees (10 years old)	28.6	803
Pruning apple trees (30 years old)	12.6	769
Thinning out surplus apples (30-year trees)	12.4	528
Pruning peach trees (8 years old)	37.7	449

In Table XXIX is shown the number of bushels of peaches that one man can pick daily where the yield per tree varies. The better the crop per tree the more it is possible to pick daily. In making these reports farmers reported those yields per tree regarding which they had the best record as to the efficiency of the picking. The larger yields are most readily reported because the most unusual. The yields per tree, therefore, should not be taken as representing the average yield of peaches. Two or 3 bushels per tree is the most common yield.

TABLE XXIX.—*A fair day's work for one man in picking peaches from trees of average size, according to yield per tree.*

Yield per tree (bushels).	Bushels picked per day.	Number averaged.
1	22.2	17
2	33.6	101
3	34.7	99
4	38.3	50
5	39.8	50
8	45.9	13
10	54.3	7

From Table XXX it appears that about the same number of peaches can be handled daily by one man packing into baskets as can be picked from the tree. In general, the smaller the basket, the less the quantity that can be packed in a day. The ⅓-bushel basket is most commonly used. Mechanical graders for sorting peaches were almost unknown in this area at the time these data were collected. The work covered by the tables, therefore, refers to methods which are entirely manual.

TABLE XXX.—*A fair day's work for one man in packing peaches in baskets.*

Size of basket (bushels).	Number of baskets daily.	Average bushels daily.	Number averaged.
¼	88.2	22.1	17
⅓	97.7	32.6	266
½	79.5	39.7	44
1	57.6	57.6	15

Table XXXI gives the daily duty of one man in picking apples. The larger the yield, the greater the quantity that can be picked in a day. Apples can be picked somewhat more rapidly than peaches. In good years pickers prefer to be paid by the bushel or barrel and work more rapidly than when paid by the day. Under average conditions in this territory the yield of apples is from 4 to 6 bushels per tree, and the average picker gathers from 20 to 25 barrels daily.

TABLE XXXI.—*A fair day's work for a man in picking apples.*

Yield per tree (bushels).	Bushels per day.	Number averaged.	Yield per tree (bushels).	Bushels per day.	Number averaged.
6	53.2	11	20	66.9	207
10	54.5	88	25	75.8	81
15	63.5	199	30	78.6	150

Mechanical devices for sorting and packing apples are seldom used in western New York. A simple barrel header operated by one man as the barrels are filled constitutes the chief mechanical aid in packing apples in this region. The same general practice prevails over the entire region, the work being done by hand.

Where apples are sorted by hand and packed in barrels, the daily amounts set out in Table XXXII should normally be accomplished.

TABLE XXXII.—*A fair day's work in sorting and packing apples with the number of hands indicated.*

Crew.		Barrels daily.	Number averaged.	Crew.		Barrels daily.	Number averaged.
Sorters.	Packers.			Sorters.	Packers.		
1	1	56.7	209	3	1	98.4	27
1	2	65.4	11	3	2	115.0	37
2	1	77.4	228	4	2	124.9	9
2	2	88.7	118				

Not many of the commercial orchards in New York are over 6 miles from market. The number of trips that can be made daily with loads of fruit for distances from 1 to 8 miles is shown in Table XXXIII. The usual load is 20 to 22 barrels of apples and 55 to 60 bushels of peaches.

TABLE XXXIII.—*A fair day's work for man and team in hauling fruit to market.*

Miles to market.	Loads per day.	Number averaged.	Miles to market.	Loads per day.	Number averaged.
1	6.3	58	4	3.0	150
1½	5.6	53	5	2.3	128
2	4.8	173	6	2.1	77
2½	4.1	79	7	1.9	29
3	3.7	210	8	1.9	17
3½	3.4	38			

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INFLUENCE OF AGE ON THE VALUE OF DAIRY COWS AND FARM WORK HORSES.

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Research work in farm economics includes among other things questions relating to the value of farm animals, farm equipment, and agricultural products. Those who have occasion to buy or sell live stock are constantly confronted with the problem of weighing the many factors influencing the value of farm animals. Of these factors, the age of the animal is one that applies directly to the value of dairy cattle and farm work horses. While age is not the only factor affecting the value of these classes of animals, it is one of the most important. In determining the value of farm animals grown for meat only, which are ordinarily disposed of at an early age, this factor is comparatively unimportant.

By means of personal visits and through correspondence with many of our best informed farmers and live-stock breeders, the Office of Farm Management recently attempted to get reliable information concerning the influence of age on the values of dairy cows and farm work horses. Farm Management investigators have found that for farm data the average of a large number of estimates is almost as accurate as that of carefully kept records, provided the estimates are given by men who thoroughly know the subject under consideration. In this case all estimates were given by men each of whom has had wide experience with the class of live stock on which he furnishes information.

Note.—This bulletin is of interest to stock-raisers generally.

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The fact that the average of the estimates for each class remained practically constant after the first thirty replies had been averaged is some evidence as to the accuracy of the figures. The estimates secured by correspondence agree very closely with those secured through personal visits. While figures concerning the values of dairy cows and farm work horses were obtained from nearly every important agricultural district in the United States, most of the estimates were secured from New York, Pennsylvania, and the North Central States. In this work appreciation and depreciation were based on age only. In order to eliminate everything except age, the animal was assumed to be in perfect health and to have a fixed value at a certain age.

Four breeds of dairy cattle, Holstein, Guernsey, Jersey, and Ayrshire, were included in these investigations. No attempt was made to find the actual average value of animals belonging to any breed. Arbitrary values were assumed for a certain fixed age, merely to get a starting point from which to work. Thus for each breed estimates were based on four classes of 3-year-olds, namely, the $80 grade cow, the $100 grade, the $200 purebred, and the $300 purebred. If the cow was assumed to be with calf at 3 years of age, she was considered to have reached the same stage of pregnancy each succeeding year. In the case of purebred stock changes in the advanced registry of the cow herself, or of other animals related to her, were not considered in estimating values.

The farm work horse was assumed to have a maximum value of $250 when in his prime, which is a fair price for very good farm horses. Brood mares were excluded, as their value is not necessarily the same as that of animals kept for work only.

In so far as age affects values the tables presented in the bulletin should be helpful in buying and selling dairy cows and farm work horses, and in taking inventories. No attempt has been made to compare breeds. In fact, it is believed that none of the figures can be interpreted in such a way as to favor any particular breed.

INFLUENCE OF AGE ON VALUE OF COWS.

HOLSTEIN.

Table I shows the influence of age on the value of four classes of Holstein cows worth per head $80, $100, $200, and $300, respectively, at 3 years of age. (See fig. 1.) For each class the estimates are tabulated separately for the North Central States, the Northeastern States, and the United States, all sections. According to these estimates Holstein cows of all classes reach their maximum money value at 6 years of age. The values do not vary greatly between the ages of 4 and 8 years. After that age depreciation is rapid. The estimated values given old cows may seem a little high, but it must be remembered that only animals in health were considered. Calves and old cows are valued relatively higher in the Central States than in the East. This is doubtless due largely to the lower price of feed in the North Central States. During their years of highest production, the price of Holstein cows appears to average a little higher in the Eastern States. This difference, however, is not marked, and in the case of the $100 grade cow it is reversed.

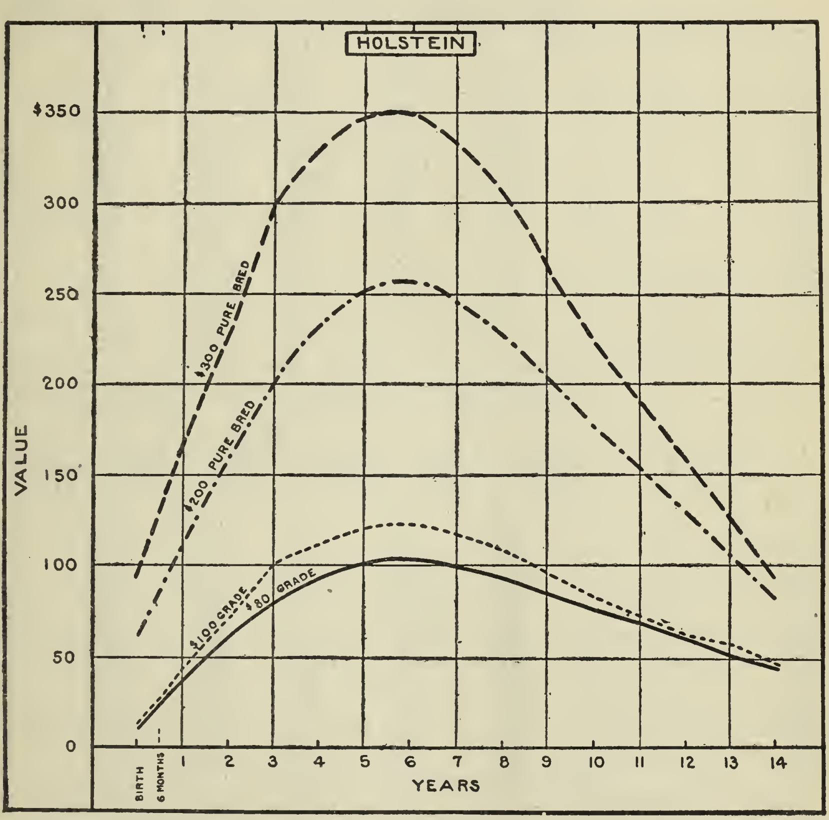

FIG. 1.—Curves showing influence of age on values of Holstein cows. (Averages of 528 estimates by owners, based on arbitrary values assumed for a certain fixed age.)

TABLE I.—*Influence of age on values of Holstein cows. (Averages of 528 estimates by owners, based on arbitrary values assumed for a certain fixed age.)*

[Averages are reported to the nearest dollar.]

Age.	Grade Holstein cow worth $80 at 3 years of age.			Grade Holstein cow worth $100 at 3 years of age.		
	North Central States.[1]	North-eastern States.[2]	United States, all sections.	North Central States.	North-eastern States.	United States, all sections.
Birth	$12	$7	$10	$13	$9	$11
6 months	28	20	24	30	22	26
1 year	43	34	39	49	39	44
2 years	63	58	61	75	71	72
3 years	80	80	80	100	100	100
4 years	90	90	91	113	110	112
5 years	98	100	100	121	120	120
6 years	**101**	**102**	**102**	**121**	**122**	**122**
7 years	98	99	99	116	115	116
8 years	92	93	93	109	104	107
9 years	82	85	84	98	92	95
10 years	74	76	75	87	78	83
11 years	67	67	67	75	69	72
12 years	60	59	60	65	60	62
13 years	52	51	52	57	52	57
14 years	46	44	44	49	46	48
Number of estimates	49	48	107	57	41	159

Age.	Purebred Holstein cow worth $200 at 3 years of age.			Purebred Holstein cow worth $300 at 3 years of age.		
	North Central States.	North-eastern States.	United States, all sections.	North Central States.	North-eastern States.	United States, all sections.
Birth	$64	$59	$62	$95	$88	$92
6 months	91	84	87	132	122	128
1 year	122	113	117	173	161	168
2 years	160	159	160	234	227	231
3 years	200	200	200	300	300	300
4 years	228	231	233	328	334	331
5 years	245	249	251	347	352	348
6 years	**252**	**257**	**256**	**348**	**354**	**350**
7 years	242	245	245	331	340	332
8 years	226	229	229	305	309	304
9 years	201	203	205	265	272	265
10 years	174	179	177	227	233	226
11 years	152	153	152	196	191	192
12 years	128	126	127	162	158	159
13 years	104	101	104	127	120	124
14 years	84	73	82	97	91	94
Number of estimates	55	44	114	98	43	148

[1] North Central States: Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota, Iowa, Nebraska, Kansas, and Missouri.

[2] Northeastern States: New England States, New York, New Jersey, and Pennsylvania.

GUERNSEYS.

Table II shows the influence of age on the values of four classes of Guernsey cows, worth per head $80, $100, $200, and $300, respectively, at three years of age. The estimates are classified as in Table I. These figures, as compared with those in Table I, indicate that appreciation and depreciation due to age are about the same for Guernseys and Holsteins. According to these estimates, Guernsey calves and old cows, like those of the Holsteins, are cheaper in the East than in the Central West. In the case of pure breds in their prime, however, the reverse is true. The estimates indicate that Guernsey cows of all classes reach their highest value at 5 and 6 years of age. (See fig. 2.)

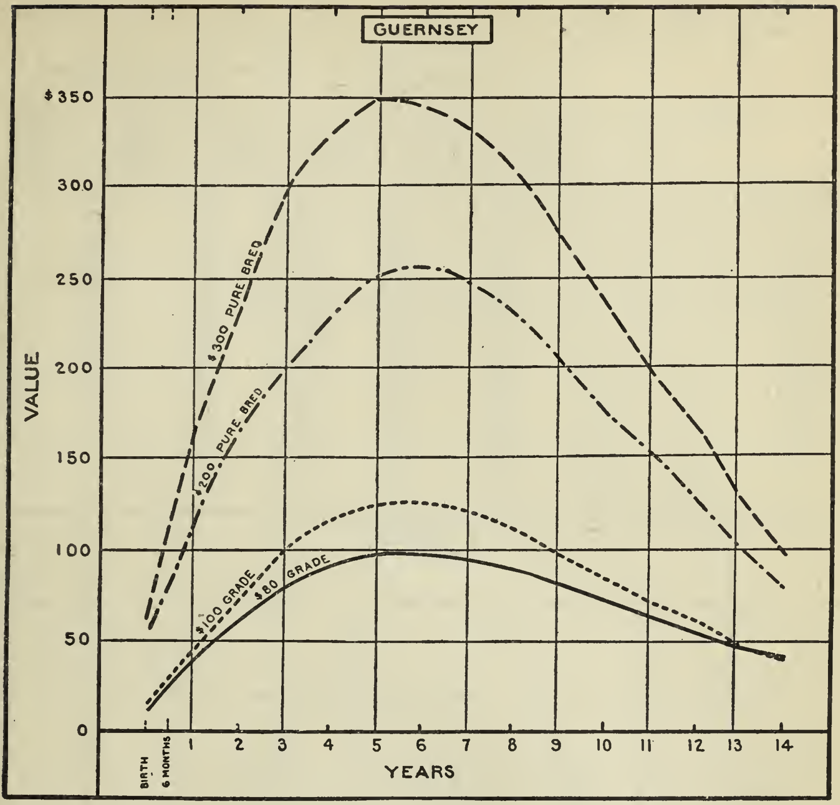

FIG. 2.—Curves showing influence of age on values of Guernsey cows. (Averages of 389 estimates by owners, based on arbitrary values assumed for a certain fixed age.)

TABLE II.—*Influence of age on values of Guernsey cows. (Averages of 389 estimates by owners, based on arbitrary values assumed for a certain fixed age.)*

[Averages as reported to the nearest dollar.]

Age.	Grade Guernsey cow worth $80 at 3 years of age.			Grade Guernsey cow worth $100 at 3 years of age.		
	North Central States.	North-eastern States.	United States, all sections.	North Central States.	North-eastern States.	United States, all sections.
Birth	$11	$10	$11	$15	$11	$13
6 months	25	21	24	30	25	27
1 year	40	38	40	48	42	45
2 years	61	58	61	74	70	72
3 years	80	80	80	100	100	100
4 years	92	90	91	116	118	117
5 years	99	**98**	**99**	127	126	126
6 years	**100**	**98**	**99**	**128**	**128**	**127**
7 years	97	96	96	123	121	121
8 years	91	91	90	115	112	111
9 years	83	81	82	100	97	97
10 years	73	72	73	87	84	85
11 years	65	63	64	74	69	71
12 years	57	53	55	63	59	61
13 years	50	46	48	52	47	49
14 years	44	39	42	42	40	41
Number of estimates	57	39	101	45	52	103

TABLE II.—*Influence of age on values of Guernsey cows. (Averages of 389 estimates by owners, based on arbitrary values assumed for a certain fixed age)*—Continued.

Age.	Purebred Guernsey cow worth $200 at 3 years of age.			Purebred Guernsey cow worth $300 at 3 years of age.		
	North Central States.	North-eastern States.	United States, all sections.	North Central States.	North-eastern States.	United States, all sections.
Birth	$57	$55	$56	$90	$71	$82
6 months	88	81	85	130	107	120
1 year	117	112	115	173	157	167
2 years	164	160	162	242	224	234
3 years	200	200	200	300	300	300
4 years	229	232	231	324	340	332
5 years	247	258	251	**337**	**363**	**350**
6 years	**250**	**264**	**257**	333	360	346
7 years	241	254	246	321	343	332
8 years	226	235	230	299	316	307
9 years	199	209	203	269	279	273
10 years	175	182	179	232	239	235
11 years	148	155	151	201	198	199
12 years	126	125	126	169	162	166
13 years	106	98	101	137	122	130
14 years	87	70	78	107	90	99
Number of estimates	31	34	70	57	50	115

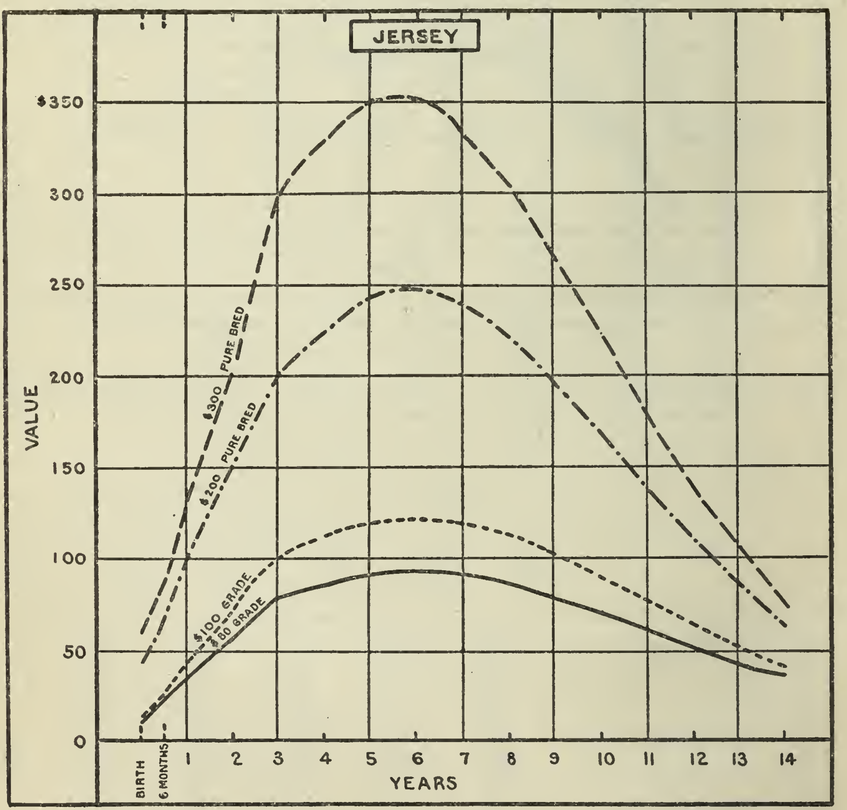

FIG. 3.—Curves showing influence of age on values of Jersey cows. (Averages of 511 estimates by owners, based on arbitrary values assumed for a certain fixed age.)

JERSEYS.

In Table III the estimates indicate that all classes of Jerseys are valued highest at 6 years, though the difference in value for 5 and 6 years is not great. Here, again, calves are rated relatively cheaper for the Northeastern States, but the regional difference in value as given for old cows is small. (See fig. 3.)

TABLE III.—*Influence of age on values of Jersey cows. (Averages of 511 estimates by owners, based on arbitrary values assumed for a certain fixed age.)*

[Averages are reported to the nearest dollar.]

Age.	Grade Jersey cow worth $80 at 3 years of age.			Grade Jersey cow worth $100 at 3 years of age.		
	North Central States.	Northeastern States.	United States, all sections.	North Central States.	Northeastern States.	United States, all sections.
Birth	$11	$8	$10	$13	$9	$12
6 months	23	19	22	26	24	26
1 year	37	32	35	44	42	44
2 years	59	56	57	72	69	72
3 years	80	80	80	100	100	100
4 years	86	87	86	110	116	111
5 years	91	93	91	119	124	119
6 years	**92**	**95**	**92**	**122**	**127**	**121**
7 years	92	93	91	121	126	119
8 years	86	88	86	116	120	113
9 years	80	82	79	105	109	102
10 years	71	74	71	92	96	89
11 years	62	62	61	79	84	77
12 years	54	52	52	66	71	64
13 years	44	42	43	54	57	52
14 years	37	34	36	43	46	41
Number of estimates	72	24	144	69	25	134

Age.	Purebred Jersey cow worth $200 at 3 years of age.			Purebred Jersey cow worth $300 at 3 years of age.		
	North Central States.	Northeastern States.	United States, all sections.	North Central States.	Northeastern States.	United States, all sections.
Birth	$42	$41	$44	$54	$50	$59
6 months	68	61	68	86	80	89
1 year	103	94	103	129	124	133
2 years	149	147	152	207	205	207
3 years	200	200	200	300	300	300
4 years	228	231	226	337	322	330
5 years	247	256	245	359	353	350
6 years	**254**	**269**	**249**	**364**	**355**	**351**
7 years	245	261	240	346	336	332
8 years	228	247	223	317	312	305
9 years	204	217	196	275	267	266
10 years	179	187	169	229	225	222
11 years	144	151	138	190	183	178
12 years	118	124	112	151	152	140
13 years	89	94	87	106	112	105
14 years	70	67	64	71	81	74
Number of estimates	52	34	137	31	16	96

AYRSHIRES.

According to the estimates averaged in Table IV, Ayrshire calves and old cows are cheaper in the Northeastern States than in the North Central States, while Ayrshire cows during their period of highest production are a little higher in the East. The values placed on old cows are exceptionally high for the North Central States. According to the estimates all classes of Ayrshires reach their maximum value at 6 years. (See fig. 4.)

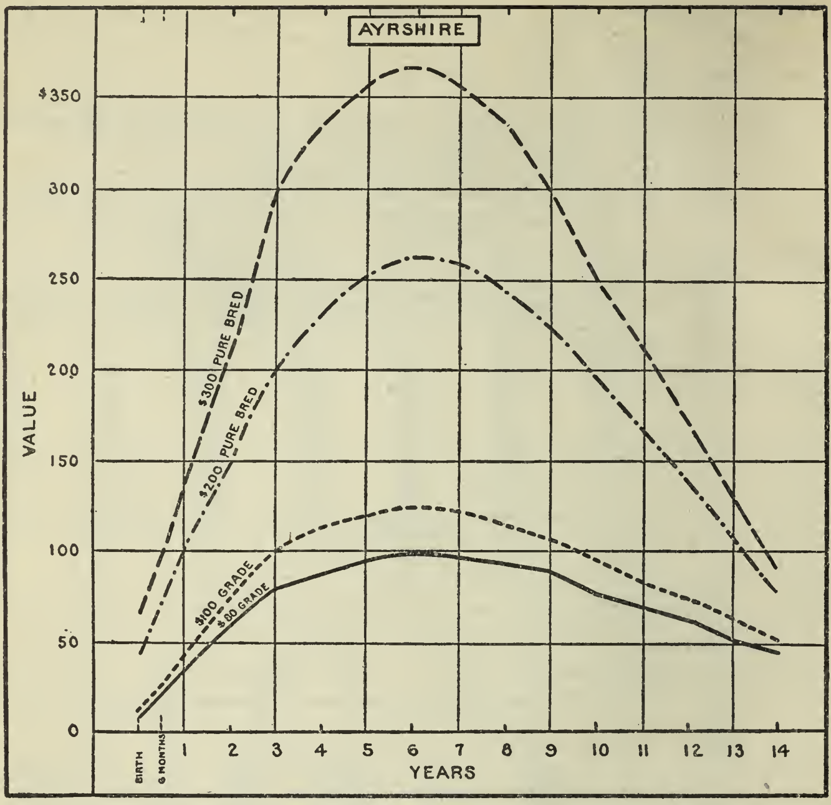

FIG. 4.—Curves showing influence of age on values of Ayrshire cows (Averages of 416 estimates by owners, based on arbitrary values assumed for a certain fixed age.)

TABLE IV.—*Influence of age on values of Ayrshire cows. (Averages of 416 estimates by owners, based on arbitrary values assumed for a certain fixed age.)*

(Averages are reported to the nearest dollar.)

Age.	Grade Ayrshire cow worth $80 at 3 years of age.			Grade Ayrshire cow worth $100 at 3 years of age.		
	North Central States.	North-eastern States.	United States, all sections.	North Central States.	North-eastern States.	United States, all sections.
Birth	$11	$8	$9	$15	$11	$12
6 months	23	20	20	30	26	26
1 year	37	33	36	48	42	43
2 years	59	55	56	76	72	73
3 years	80	80	80	100	100	100
4 years	87	89	87	109	111	111
5 years	91	96	95	114	120	119
6 years	**95**	**100**	**99**	**116**	**125**	**123**
7 years	94	100	98	114	123	121
8 years	90	96	94	108	118	116
9 years	85	88	89	99	108	106
10 years	78	79	78	90	96	95
11 years	69	71	70	79	84	83
12 years	62	61	61	69	73	73
13 years	54	51	52	60	61	61
14 years	47	43	45	52	50	51
Number of estimates	25	83	137	26	107	141

TABLE IV.—*Influence of age on values of Ayrshire cows. (Averages of 416 estimates by owners, based on arbitrary values assumed for a certain fixed age)*—Continued.

Age.	Purebred Ayrshire cow worth $200 at 3 years of age.			Purebred Ayrshire cow worth $300 at 3 years of age.		
	North Central States.	North-eastern States.	United States, all sections.	North Central States.	North-eastern States.	United States, all sections.
Birth	$44	$42	$44	$67	$65	$66
6 months	73	68	70	99	98	98
1 year	108	101	103	145	138	140
2 years	155	148	150	224	210	212
3 years	200	200	200	300	300	300
4 years	233	228	230	322	335	333
5 years	243	255	253	345	361	357
6 years	**250**	**266**	**262**	**355**	**371**	**367**
7 years	245	265	258	342	360	355
8 years	233	252	244	322	342	335
9 years	209	229	222	290	299	296
10 years	191	202	196	248	252	250
11 years	166	168	165	210	212	210
12 years	142	132	134	172	171	170
13 years	113	99	103	130	130	129
14 years	87	74	78	100	90	90
Number of estimates	23	51	79	10	46	59

GENERAL DISCUSSION OF PRECEDING TABLES.

With few exceptions, the preceding tables indicate that calves and old cows are cheaper in the Northeastern States, and that cows between the ages of 4 and 8 are cheaper in the North Central States. For all breeds, and for all classes of all breeds, the price of cows in health is greatest between 5 and 7 years, with the maximum usually at 6. They are valued about the same at 4 as at 8. The explanation for this may be that though the younger animals have before them a longer period of usefulness, the older ones have already demonstrated their worth. In all the tables the 14-year-old values for pure-bred cows are much greater than for grades. This may be partly due to higher average milk production, but it is undoubtedly more largely due to the possibility that these cows may yet produce valuable calves.

The cow worth $80 at 3 years of age is given a birth value of about $10, while the cow worth $100 at that age is given a birth value of about $12. Similarly the difference in value between the two classes of pure-bred cows at 3 years of age is $100, while the difference in value at birth is in no case above $30, leaving a margin of at least $70 to cover interest on larger investment, risk of a greater possible loss, and any extra expense for feed or care.

TABLE V.—*Influence of age on values of dairy cows, shown in per cent of maximum value. (Averages of 1,844 estimates by owners, based on arbitrary values assumed for a certain fixed age.)*

Age.	Grade cows worth $80 at 3 years of age.				Grade cows worth $100 at 3 years of age.			
	Holstein.	Guernsey	Jersey.	Ayrshire.	Holstein.	Guernsey.	Jersey.	Ayrshire.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Birth	10	11	11	9	9	10	10	10
6 months	24	24	24	20	21	21	21	21
1 year	38	40	38	36	36	35	36	35
2 years	60	62	62	57	59	57	60	59
3 years	78	81	87	81	82	79	83	81
4 years	89	92	94	88	92	92	92	90
5 years	98	**100**	98	96	98	99	98	97
6 years	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
7 years	97	97	98	99	95	95	98	98
8 years	91	91	94	95	88	87	93	94
9 years	82	83	82	90	78	76	84	86
10 years	74	74	77	79	68	67	74	77
11 years	66	65	66	71	59	56	64	67
12 years	59	56	56	62	51	48	53	59
13 years	51	48	47	52	47	39	43	50
14 years	43	42	39	45	39	32	34	41
Number of estimates	107	101	144	137	159	103	134	141

Age.	Purebred cows worth $200 at 3 years of age.				Purebred cows worth $300 at 3 years of age.			
	Holstein.	Guernsey.	Jersey.	Ayrshire.	Holstein.	Guernsey.	Jersey.	Ayrshire.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Birth	24	22	18	17	26	23	17	18
6 months	34	33	27	27	36	34	25	27
1 year	46	45	41	39	48	48	38	38
2 years	62	63	61	57	66	67	59	58
3 years	78	78	80	76	86	86	85	82
4 years	91	90	91	88	94	95	94	91
5 years	98	98	98	97	99	**100**	99	97
6 years	**100**	**100**	**100**	**100**	**100**	99	**100**	**100**
7 years	96	96	96	98	95	95	94	97
8 years	89	89	90	93	87	88	87	91
9 years	80	79	79	85	76	78	76	81
10 years	69	70	68	75	64	67	63	68
11 years	59	59	55	63	55	57	51	57
12 years	50	49	45	51	45	47	40	46
13 years	41	39	35	39	35	37	30	35
14 years	32	30	26	30	27	28	21	24
Number of estimates	114	70	137	79	148	115	96	59

Table V is a percentage table based on the data given in the preceding tables. It is believed that within reasonable limits the per cent columns will be found useful in estimating the values of other classes of dairy cows. For example, the per cent column for the cow worth $80 at 3 years of age should be approximately accurate for the cow worth $70 at 3 years of age, and the per cent column for the cow worth $100 at 3 years of age should be approximately accurate for the cow worth $110 at 3 years of age. On the other hand, the per cent column for the purebred cow worth $300 at 3 years of age, could not very well be applied to cows valued at twice the amount at that age.

All classes of live stock vary in actual value from time to time, but such variation does not greatly affect the relative value of the animal at different ages. A cow worth $100 at 3 years of age when there is a great demand for dairy cattle will be worth less at the same age when there is smaller demand, but there will be a corresponding fluctuation in value for all other ages. It is, therefore, believed that the tables, especially the percentage table, will be found useful in determining relative value according to age.

Figures 1, 2, 3, and 4 present in graphic form the data for each class of all four breeds as given in Tables I, II, III, and IV. These curves indicate that the difference in value between the various classes of the same breed is greatest when the animals are in their prime and least for calves and old cows. It is also clearly shown that the curvature increases for each succeeding class from the $80 grade to the $300 purebred. This may be explained in part by saying that the price of grade cows is influenced largely by production, that the price of the $200 purebred includes production and registration, and that in determining the price of the $300 purebred three major factors must be considered, production, registration, and advanced registry.

INFLUENCE OF AGE ON VALUE OF WORK HORSES.

TABLE VI.—*Influence of age on values of farm work horses.* (*Averages of 147 estimates by owners, based on an arbitrary value at prime.*)

Age.	Maximum value, $250.	Per cent of maximum value.	Age.	Maximum value, $250.	Per cent of maximum value.
		Per cent.			
Birth	$39	16			*Per cent.*
6 months	63	25	9 years	227	91
1 year	96	38	10 years	209	84
2 years	142	57	11 years	190	76
3 years	185	74	12 years	174	70
4 years	220	88	13 years	154	62
5 years	242	97	14 years	137	55
6 years	248	99	15 years	119	48
Maximum	250	100	16 years	101	40
7 years	247	99			
8 years	241	96	Number of estimates	147	....

Table VI shows the estimated influence of age on the value of farm work horses, and the per cent that the value at any age is of the maximum value. The estimates are for the farm horse worth $250 in his prime. This is a value much above that of the average farm work horse, but the per cent columns may be used within reasonable limits in determining the influence of age on the values of cheaper farm horses. According to these figures the farm work horse reaches his maximum value at some point between six and seven years of age.

If still in health his value at 16 years is 40 per cent of his maximum value. At birth he is worth 16 per cent of his maximum value, and there is little change in value between the ages of 5 and 9.

Figure 5 presents in graphic form the data given in Table VI. This curve differs in some respects from the curves for purebred dairy cows and is altogether different from the curves for grade dairy cows. As compared with the values given for pure-bred dairy cows of about the same maximum value, the birth value of horses is considerably less, the age of maturity a little later, and the old-age value somewhat higher.

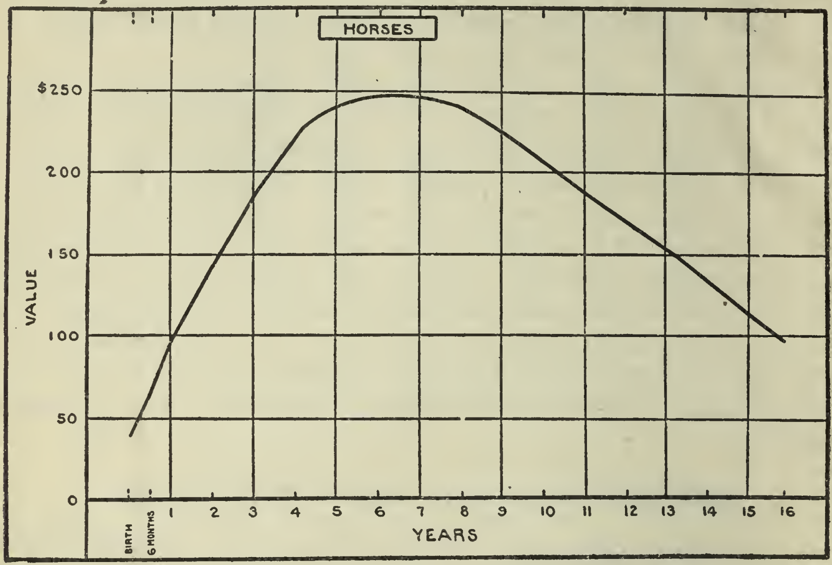

FIG. 5.—Curve showing the influence of age on the values of farm work horses. (Averages of 147 estimates by owners.)

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CONVICT LABOR FOR ROAD WORK.

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INTRODUCTION.

Within recent years the policy of utilizing convict labor in road construction or in the preparation of road materials has received serious attention by State legislatures, and a number of the States are now actively employing convicts on road work, while other States are earnestly seeking information on the subject.

Among the many problems involved are the following:

(1) Whether it is profitable to use convicts for road construction, and if so, under what conditions;

(2) The systems of discipline and management productive of the best results;

(3) The character and economy of structures and equipment best adapted to conditions in various sections of the country;

(4) The character, preparation, and cost [1] of food;

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[1] It must be borne in mind that all prices of foodstuffs, clothing, and camp equipment herein quoted are those prevailing in 1915.

NOTE.—This bulletin is intended to give State officials in charge of road work accurate and comprehensive information on the use of convict labor for building roads.

(5) The steps necessary to secure proper sanitation and hygiene;

(6) The most suitable system of cost keeping and record;

(7) Detailed and comparative cost data on every phase of the subject.

As no single State can answer these varied and perplexing inquiries, an exhaustive investigation has been conducted by the Office of Public Roads and Rural Engineering in cooperation with the United States Public Health Service during a portion of the calendar years 1914 and 1915. Personal visits were made to convict camps and conferences were held with State highway and prison officials in the States of New York, New Jersey, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Alabama, Florida, Mississippi, Louisiana, Texas, Michigan, Colorado, New Mexico, Arizona, Utah, Wyoming, California, Washington, and Oregon. On these visits the most searching inquiries and inspections were made covering administrative, engineering, economic, disciplinary, and health conditions at the camps.

These personal investigations were supplemented by correspondence with prison and highway officials in all parts of the country, and in addition many Government publications, State documents, treatises, and reference works were consulted in the preparation of this bulletin.

It is the purpose of the authors to cover as nearly as possible all questions that might arise in connection with either the adoption of a policy relating to the use of convict labor in road work or the actual working out of such a policy. To this end a presentation and discussion of the principles involved, a digest of convict road laws, and a discussion of every phase of operation are embodied in the bulletin, together with specific detailed instructions for the carrying out of all recommendations which the authors make.

In the course of the investigation much valuable and detailed information was obtained which could not be brought within the limits of a bulletin. This information, however, is filed in the Office of Public Roads and Rural Engineering, and inquiries which may not be answered with sufficient completeness in the bulletin may be covered adequately by correspondence.

SYSTEMS OF CONVICT LABOR.

In order to weigh the relative advantages and disadvantages of utilizing convict labor in public highway construction and other occupations, a knowledge of the systems of convict labor in operation is helpful. These systems, six in number, are known as the lease, the contract, the piece-price, the public-account, the State-use, and the public-works-and-ways systems, respectively, and are explained as follows.

LEASE SYSTEM.

Under this system the State disposes of its convicts to private lessees, who agree to become responsible for guarding, clothing, feeding, transporting, and giving medical attention to the convicts under rules specified by the State. The lessees provide steady employment for the convicts and pay to the State an agreed amount, the State providing for adequate inspection to insure enforcement of its rules. This system, formerly widely practiced, has been abandoned in all States except Florida, and exists there in only a modified form. It is therefore unnecessary to set forth its intrinsic defects.

CONTRACT SYSTEM.

Under this system the State sells the labor of the convicts, but does not relinquish its care or control. As generally practiced, the State maintains an institution and guards, feeds, clothes, and houses the convicts, and provides medical attention, while the contractor supplies the raw material, superintends the work, and pays a stipulated amount per capita for the labor. This system is now practiced in whole or in part by the following 18 States: Alabama, Connecticut, Delaware, Indiana, Iowa, Kentucky, Maryland, Missouri, Nebraska,[1] New Hampshire, North Carolina, South Carolina, South Dakota, Tennessee, Vermont, Virginia, West Virginia, and Wisconsin.

The contract system is an advance over the lease system, as the contractor assumes the responsibility for profit and loss, the State is assured a definite income, and the interests of the prisoners are safeguarded by the prison officials. There is, however, a tendency to conflict of interests and responsibility between the representatives of the contractor and of the State. In addition, a most powerful objection to the contract system is advanced by organized labor and by manufacturers, to the effect that its product comes into direct competition with the product of free labor.

PIECE-PRICE SYSTEM.

This system differs from the contract system only in the manner of payment for and supervision of the work. The contractor, instead of paying for the labor of the convicts, pays an agreed amount for each piece or article manufactured. Usually under this system the State supervises the work, but this is sometimes done by the contractor. Under the former plan the prison officials must possess ability to manage the industrial as well as the penal features of the work. At present this system is practiced in whole or in part in Alabama, Connecticut, New Jersey,[2] and Rhode Island.

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[1] The contract system is now being discarded in Nebraska in favor of the State-employment plan, and experiments are being made with road and farm work.

[2] The piece-price system was abolished in New Jersey by act of the legislature in 1911, but no fund was provided for any other system, hence it is still in force on a day-to-day basis.

PUBLIC-ACCOUNT SYSTEM.

Under this system the private contractor is eliminated entirely, as the State, in addition to maintaining its own penal institution, conducts all of the industries in which the convict labor is utilized, and maintains its own selling organization to dispose of the product. The principal difference between the piece-price system and the public-account system is that in the latter the profit derived from convict labor goes to the State instead of to the private contractor. This system is now followed in whole or in part by the following 19 States: California, Illinois, Indiana, Kansas, Maine, Massachusetts, Michigan, Minnesota, Mississippi, New Mexico, North Carolina, North Dakota, Pennsylvania, South Dakota, Tennessee, Texas, Washington, Wisconsin, and Wyoming.

STATE-USE SYSTEM.

The only difference between this and the public-account system lies in the disposal of the product, as under the public-account system the product is sold and under the State-use system it is limited to the use of State institutions. This system is more widely followed than any other, and is now in effect in whole or in part in the States of Arizona, Arkansas, Colorado, Connecticut, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Montana, New Hampshire, New Jersey, New Mexico, New York, Nevada, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Tennessee, Utah, Virginia, Washington, West Virginia, Wisconsin, and Wyoming. A smaller measure of competition with free labor is involved in this system than under those already described, and it encroaches in a lesser degree upon the field of the private manufacturer. The serious objections to the system are that the State institutions require a great variety of articles, while the demand for each individual article may be quite limited. Obviously, the State can not equip its penal institutions to manufacture all of the articles used by State institutions, and if it devotes its efforts to the production of a few of such articles the demand may not be sufficient to furnish full-time employment for the convicts.

PUBLIC-WORKS-AND-WAYS SYSTEM.

This system, which has been gaining ground in recent years, involves the use of convict labor in the construction and repair of public buildings, public highways, breakwaters, levees, drainage and irrigation ditches, and similar works rather than in the production of marketable articles or merchandise, and it is under this system that the prominence of convict labor as a factor in highway improvement finds its place. It can be seen readily that under this system there is less competition with free labor and none with manufacturers, but, on the contrary, the creation of public utilities by means of convict labor is more than likely to give greater employment to free labor and to create a greater demand for the products of the manufacturer. This system is now practiced in whole or in part by the following 27 States: Arizona, Arkansas, California, Colorado, Delaware, Florida, Georgia, Illinois, Kentucky, Louisiana, Montana, New Jersey, New Mexico, New York, Nevada, North Carolina, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, and Wyoming.

The above list includes only those States in which prisoners of the State penitentiary are being employed under the public-works-and-ways system and not those, such as Alabama, Maryland, Michigan, and others, in which county convicts or prisoners of State institutions other than the penitentiary are so used.

TREND OF THE WORK SYSTEMS, 1885-1915.

In order to indicate the trend of convict labor under the systems above described, Table 1 has been prepared, in which the statistics for 1885 and 1903–4 were compiled from annual reports of the Commissioner of Labor, and the statistics for 1914–15 were obtained by correspondence conducted by this office with 186 of the 296 institutions mentioned in the 1903–4 report of the Commissioner of Labor. The statistics in the table are based upon the daily average number of inmates engaged in productive work under the respective systems.

TABLE 1.—*Convicts employed under various systems from 1885 to 1915.*

System of work.	1885		1903–4				1914–15	
			296 institutions.		186 institutions.		186 institutions.	
	Number.	*Per ct.*	*Number.*	*Per ct.*	*Number.*	*Per ct.*	*Number.*	*Per ct.*
Lease	9,104	20.1	3,652	7.1	2,925	8.4	950	1.4
Contract	15,670	34.6	16,915	33.1	12,126	34.7	6,981	10.6
Piece price	5,676	12.5	3,886	7.6	2,000	5.7	1,193	1.8
Public account	14,827	32.8	8,530	16.7	6,128	17.6	11,807	18.0
State use			12,045	23.5	7,152	20.6	33,805	51.4
Public works and ways			6,144	12.0	4,542	13.0	11,063	16.8
Total	45,827	100.0	51,172	100.0	34,873	100.0	65,799	100.0
Total of public-account, State-use, and public-works-and-ways systems	14,827	32.8	26,719	52.2	17,822	51.2	56,675	86.2

In 1885 the State-use and public-works-and-ways systems were not reported separately, as all such work was then classified under the public-account system. Therefore, in order to render a comparison practicable, the table shows for each of the periods mentioned the total number of convicts employed for the benefit of the State. It should be noted that the table shows quite clearly the decline in the number of convicts employed by private industries under the lease, contract, and piece-price systems, and the increasing tendency to adopt those systems under which the convict is employed entirely for the benefit of the State.

ROAD WORK FOR CONVICTS.

In much of the discussion of the proposition of road work for convicts, there is evident a popular belief that the employment of convicts in the open air, which such work entails, is a radical departure from well-established principles and a development of very recent origin. Nothing could be further from the truth. Such employment has been in practice at one time or another in all countries, and among the ancient nations no other method of employment was known. The ancient prisons were places of detention and torture only; labor formed no part of their regimen. But there are numerous references in history to the employment of prisoners of war and of criminals on the public works of the ancient kingdoms and almost invariably these works were performed necessarily in the open air. In fact, the provision of indoor labor is of comparatively modern origin and dates back no further than the development of the workhouse in the sixteenth century, while the penitentiary, as now known, is practically a product of the nineteenth century.

In America perhaps the earliest record of the employment of prisoners on public works is found in statute 29 of the Virginia Colonial Assembly, enacted in 1658.

Somewhat later in the French colony of Louisiana, it is recorded that "Bienville, reappointed governor (1718), intending to found a town on the river, set a party of convicts to clear up a swamp—the site of the present city of New Orleans."[1]

However, the criminal class in the majority of the colonies, with the exception of those convicts who were sent to them by the mother country as "servant criminals," was very small, and there seems to have been no general system of labor as a punishment for those convicted within their boundaries. Indeed, as all who are familiar with the colonial history of America are aware, the barbarous practices of tongue splitting, branding, burning at the stake, whipping, ducking, and exposure to the public gaze in the stocks and pillory were the methods most favored by the good colonists for the punishment of their own offenders, and the number of crimes for which the death penalty was prescribed was very large.

After the close of the Revolution, one of the earliest measures in Pennsylvania "was in the direction of reforming the Penal Code, and in 1786 an act was passed providing that certain crimes, which until then had been capitally punished, should thereafter be punished by labor 'publicly and disgracefully imposed.' Under this law the convicts were employed in cleaning streets, repairing roads, etc., their heads were shaved, and they were clothed in a coarse uniform."[1]

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[1] History of the United States, by Rich and Hildreth, vol. 2, p. 281.

But as will be noted, the motive which inspired this early experiment in convict road building in the United States was wrong, and its effect is best described in the words of "a most respectable eyewitness," as reported by William Crawford, esq., in his report "to Lord Viscount Duncannon, His Majesty's principal secretary of state for the home department" in 1834 on "The Penitentiaries of the United States." He said:

> The directions of the law of 1786 were soon found to be productive of the greatest evils, and had a very opposite effect from what was contemplated by the framers of the law. The disorder in society, the robberies, the burglaries, breaches of prison, alarms in town and country, the drunkenness, profanity, and indecencies of the prisoners in the streets, must be in the memory of most. With these disorders the number of criminals increased to such a degree as to alarm the community with fears that it would be impossible to find a place either large or strong enough to hold them. The severity of the law and the disgraceful manner of executing it led to a proportionate degree of depravity and insensibility and every spark of morality appeared to be destroyed.

For these reasons the law of 1786 was repealed and in 1790 the first penitentiary in the United States was constructed in Philadelphia. All convict labor in the State of Pennsylvania was thereafter performed within its walls.

Following this example penitentiaries were established in rapid succession in Connecticut, New York, Virginia, Massachusetts, Vermont, Maryland, New Hampshire, Ohio, New Jersey, Tennessee, Kentucky, Maine, District of Columbia, Indiana, Georgia, and Illinois. In 1834 when William Crawford, esq., made his report to Lord Viscount Duncannon, the following were still without them: The States of Rhode Island, Delaware, North Carolina, South Carolina, Alabama, Mississippi, Louisiana, and Missouri, and the Territories of Florida, Michigan, and Arkansas.

From the above classification it will appear that, in general, the Northern and Eastern States were provided early with penitentiaries, whereas the Southern and Western States had no such institutions. The same classification may be made in respect to the system of labor provided for the employment of the convicts. Whereas the Northern and Eastern States adopted the contract and State-account systems and employed their prisoners in indoor workshops, the practice of leasing convicts to private persons for outdoor work was followed in the South and West practically from the foundation of the Republic.

The reasons for these early differences are readily seen in the different conditions and environment of the two sections—North and

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[1] Report of the Commissioners on Penal Code of Pennsylvania, p. 13.

South. In the North the severity of the winter climate rendered much outdoor work during that season impracticable. If the convicts were to be employed the year round—and it was recognized that they should be—it was necessary to provide the means of such employment indoors during the winter season; and the institution once established with provision for indoor work, the easy and obvious thing to do was to make use of it winter and summer. In the South, on the other hand, it was thought by many persons that the hot, summer climate would be unfavorable to the employment of prisoners indoors during that season, while the mild climate permitted outdoor work at all seasons. Conditions were the reverse of those existing in the North and the pursuit of the same logic in the two sections resulted in the two opposing methods.

In addition to the effect of the difference in climate upon the employment of convicts in the North and South, respectively, industrial conditions caused by the development of large ports and manufacturing centers in the North, as contrasted with the extension of the plantation system of agriculture in the South, further accentuated the tendency to indoor employment in the North and outdoor in the South. In the North it followed logically that the convicts should be employed in manufacturing, which was the prevailing occupation of the community. The industries were the manufacture of boots and shoes, hollow ware, cooperage, harness, shirts, overalls, and other articles of trade. The same logic of conditions caused the working of the convicts in the South at outdoor tasks, such as in the mines, in the lumber and turpentine industries, in the construction of railroads, and, to some extent, in farming. As has been shown from the early experience of Pennsylvania, the attempt to employ convicts outdoors in the midst of a comparatively dense population brought about such intimate contact of convicts and public as to degrade the former and seriously to affect the order and well-being of the latter. This objection could not be raised in the South, where the population was comparatively sparse and widely distributed on plantations and manors, and where the convict, working out of doors, would fall under the observation of only occasional travelers on the lightly traveled highways.

After the failure in Pennsylvania, convicts had been rarely used in the United States on public works until nearly 1880. In England, the various attempts to abolish the system of convict transportation led somewhat earlier to the extensive and profitable use of convicts in this way, notably in the construction of the Portland breakwater, which was begun in 1848, and upon which an average of 1,000 convicts were employed for almost 25 years. In the United States the first of the modern laws permitting the regular employment of convicts on public works appears to have been passed by the legislature of North Carolina in 1867. This law provided for the employment of county convicts on county roads in case any county should desire to use them. Subsequently similar laws were passed in North Carolina in 1873, 1875, 1877, 1879, and 1889. But the first work attempted on a practical scale under these laws was conducted by Mecklenburg County, in 1885.

Previous to this work had been begun by a few counties in the States of Georgia and Tennessee; but, though there developed immediately a considerable sentiment in favor of such employment, the use of convicts on the roads in the South did not become general until about 1890. Even then the convicts so employed were county convicts, and in practically all of the Southern States the State prisoners still were employed in other ways under the lease system.

About this time interest in the improvement of the roads of the country having been stimulated largely by the advent of the bicycle, the plan of using State convicts to accomplish the necessary work was widely agitated, and this led to the settled policy in the South of employing the convicts in that manner. For a time the Northern and Western States rejected the idea upon the ground that such labor would entail the degrading exposure of the convict to the public gaze, the same reason that had caused the abolition of the plan in Pennsylvania in 1790. In 1893 the new road law in Delaware provided for the purchase of a stone quarry and the preparation by the prisoners of stone for road work, and shortly afterward a more elaborate plant of this character was established at Folsom prison in California. New Jersey and New York also were among the first of the Northern States to enter into work of this sort. But the employment of prisoners in the actual construction of highways in the North and West is a development of the last ten years; and the reason which ultimately prompted the action in these sections were not economic considerations as in the South, but the desire to relieve the overcrowded condition of the penitentiaries, to furnish employment that would conflict as little as possible with the interests of free labor and to provide a particular form of employment for certain prisoners of the better sort.

Table 2 shows the number of prisoners and the percentages of the total prison population employed in indoor and outdoor work, and on road construction only, in the years 1885, 1903–4, and 1914–15, in a number of representative institutions in the United States. The figures for 1885 and 1903–4 were taken from the reports of the Bureau of Labor and those for 1914–15 were obtained by correspondence. In this table, as in Table 1, the figures for the latest period represent only 186 of the 296 institutions included in the full report for 1903–4; but a comparison on the basis of identical institutions is made possible by the inclusion of the third and fourth columns of 1903–4.

This table shows that, though the proportions of convicts employed in indoor and outdoor work have not changed greatly since 1885, the numbers and percentages of convicts employed in road work have steadily increased from 584, or 1.3 per cent of the total convict population represented in 1885, to 8,341, or 12.7 per cent of the convict population represented in 1914–15. That the percentage of prisoners engaged in outdoor work has not increased correspondingly may be due to the partial substitution of road work for railroad building, lumbering, the turpentine industry, farming, and other forms of outdoor work.

TABLE 2.—*Convicts employed in indoor and outdoor work and in road work in 1885, 1903–4, and 1914–15.*

Employment.	1885		1903–4				1914–15 186 institutions.	
			296 institutions.		186 institutions.			
	Number.	*Per ct.*	*Number.*	*Per ct.*	*Number.*	*Per ct.*	*Number.*	*Per ct.*
Indoor work	28,280	62.5	28,479	55.7	19,967	57.3	36,036	55.8
Outdoor work	16,997	37.5	22,693	44.3	14,906	42.7	28,593	44.2
Total	45,277	100	51,172	100	34,873	100	64,629	100
Road work	584	1.3	3,508	6.8	2,497	7.1	8,341	12.7

A number of the States are now using convict labor in the construction of roads largely because present conditions have forced a change in the old methods of employing the prisoners, and it is probable that other States, sooner or later, will find themselves in the same position. In the South the sentiment against the leasing of convicts has reached the point where it was imperative to evolve some other system. At the same time most of these States were inadequately equipped for the housing of the entire convict population, and in a few there were no State penal institutions at all. Under these circumstances it was impossible to provide indoor work of any character for all the convicts, and, as in those States there is a pressing need for the improvement of highways, the employment of the convicts in highway construction has seemed to offer the best solution of both problems.

Throughout the country the opposition by skilled free labor to the direct competition of convict labor in the manufacture of trade articles has become so pronounced as to make the abandonment of such competitive work almost necessary, and the adoption of either, or both, the State-use system and the public-works-and-ways system has seemed the only alternative. Experiment with the State-use system in a number of the States has revealed the fact that large prison populations can not be employed conveniently at full time under the system alone by reason of the limited demand of the State institutions and departments for such articles as the prisons can be equipped to manufacture. Hence prison officials have been forced to look to road work, farm work, or similar outdoor labor to find a medium for the employment of their charges.

In a number of States the large increase in the criminal population has resulted in the overcrowding of the old penitentiaries; while, in the light of modern knowledge of sanitation, some institutions have been found to be a menace to the health of their inmates. Road work or other outdoor employment seems to offer the best solution of these problems of sanitation and health.

Finally, the general impression is that convict road labor is cheaper than the same class of free labor, and there is a consequent demand for such labor on the part of counties and smaller political units with limited funds for necessary road work at command.

In all of the States one or more of these conditions exist, and in a number the resort to the employment of the convicts on road work has proved satisfactory, both from the economic and from the humanitarian standpoint. The scheme has both valuable and objectionable features, the most important of which are detailed below, but a full consideration of its advantages and drawbacks seems to show that such employment for at least a part of the prisoners of all the States might be provided with good results.

Of all the advantages that are urged in favor of road work as an occupation, that which carries the greatest force is that such work undoubtedly is more healthful than any form of employment which may be provided in a prison shop. Hard manual labor, in close touch with nature and its fresh air and sunshine, is universally recognized as most beneficial, while continuous dwelling within doors, with only such periods of exercise in the open as it is convenient to allow, is a most unnatural life for all but a small proportion of the State's prisoners, and is observed to have a depressing effect upon the vitality of most of the convicts, with no marked good effect upon any of them.

TABLE 3.—*Classification of convicts in 22 representative States according to employment prior to arrest.*

Name of State.	Percentage of total population by occupations.				
	Professional.	Merchants and tradesmen.	Outdoor laborers, skilled and unskilled.	Shop workers and indoor laborers.	Unemployed.
New England group:					
Connecticut	5	5	49	41	....
New Hampshire	10	2	56	31	1
Middle Atlantic group:					
New York	12	9	48	30	1
Pennsylvania	5	4	64	27	....
Maryland	5	2	67	26	....
Southeastern group:					
South Carolina	4	....	77	19	....
Georgia	1	1	92	6	....
Louisiana	4	1	83	12	....
Middle Western group:					
Illinois	14	7	48	31	....
Indiana	6	8	61	25	....
Iowa	7	5	67	21	....
Minnesota	7	6	65	21	1
Western group:					
Montana	7	6	63	23	1
Idaho	11	1	73	15	....
Wyoming	8	2	70	20	....
Utah	6	1	62	31	....
Oregon	9	4	63	24	....
Colorado	11	6	56	27	....
New Mexico	3	1	80	16	....
Arizona	8	1	79	12	....
California	13	5	50	31	1
South Dakota	8	5	68	19	....
Average by States	7.43	3.75	65.50	23.09	0.23

The desirability of providing open-air work, as on roads, is enhanced by the fact, shown by the prison statistics of practically all States, that a majority of the prison inmates are of the laboring class or of those classes whose habits of life prior to conviction kept them much of the time out of doors, engaged in occupations similar to those afforded by the various phases of road work. As an indication of the strength of this argument, Table 3 has been prepared, based upon the latest reports of the penitentiaries in the 22 States which were selected as typical of conditions in the various sections of the country. All convicts in these States have been grouped into five classes according to their occupation prior to conviction, namely: Professional; merchants and tradesmen; outdoor laborers, skilled and unskilled; shopworkers and indoor laborers; and unemployed. The table shows that an average of practically two-thirds of the inmates of the institutions represented were engaged in outdoor occupations, that about one-tenth belonged to the professional and mercantile classes, and that only about one-fourth of all the convicts were fitted to endure the confinement of life in penitentiary shops. Upon members of all but the fourth class, then, such confinement has an undoubted physically degenerating effect, and particularly leaves the outdoor laborers unfitted to resume their former work after discharge.

Aside from its deleterious physical effect, the monotony of prison-shop labor has a tendency to reduce the mental activity of the inmate unused to such life, and upon release many of the members of the professional and mercantile classes find themselves no longer able to keep pace with their more alert competitors. Work on the roads offering, as it does, a variety of employment has no such degenerative mental effect, and for this reason is better than shopwork as an occupation for about three-fourths of the prison population.

But leaving entirely out of the question the superior mental and physical advantages of road work or similar outdoor work, a majority of prison officials favor such work for the reason that it removes the convict as far as possible from competition with free labor. It is true that no matter what form of employment be adopted for prisoners, unless it be entirely unproductive, the interests of free laborers will be affected to a greater or less extent; but, by reason of the fact that it is performed in the interests of the public only, that it enriches no private employers of labor to the injury of the free laborer, and that its product is not placed on competitive sale with that of free labor, road work is certainly no more injurious to the interests of the latter than such work as is performed under the State-use system. What is more, in many localities the convict is not depriving the free laborer of work, since much of the road work performed by convicts could not be undertaken at all, for financial reasons, if it were necessary to employ free labor.

Another very important consideration in regard to road work is that it is extremely productive to the public. No field can be selected in which the expenditure of prison labor can be applied with greater benefit to the States, for the reason that, as a whole, there is no greater public need than the improvement of the highways. It is true that the value of such labor can not be measured so readily in dollars and cents as the industrial labor within the penitentiaries, but there is every reason to believe that, properly conducted, the road work may be carried on with as much efficiency as the penitentiary industries, while the former has the additional advantage of requiring no sale or transfer to place it in public use. At this point let it be noted that, although the convict's labor, so applied, may be of very great benefit to the State, it also is of benefit to the convict himself in that it brings to him the realization he can not grasp in the prison-shop grind, that he may be of real importance in life as a producing agent. Through the promotion of his self-esteem in the useful works of the construction camp, there is created the desire to merit the good opinion of his fellows, without which reformation is impossible.

When, as practiced in a number of States, assignment to the road camp is reserved as a reward for those prisoners who have proved in close confinement their merit and good intention, the reformative value of the road labor is further enhanced by the progression from the restriction of bars and locks to the freer regulation of the camp. By doing away with all marks of degradation, such as stripes and chains and shaven heads, by permitting the exercise of more and more initiative, and the granting of an increasing degree of freedom as the ability to use it properly is manifested, the very publicity of the convict's position on the roads is transformed from a mark of disgrace to an acknowledgment of the confidence of his keepers; and by practice in self-restraint and proper living under guidance in the camp he is fitted to live a life of similar circumspection after discharge. That such is the actual effect of the employment of convicts on the roads is the testimony of all prison officials who have employed such a system and who point out that the number of recidivists in their populations is markedly reduced.

Finally, as implied above, it is possible to make the road work, when carried on in conjunction with other industries inside the walls, a very useful factor in the discipline of the penal institution. All prisoners appreciate the opportunity of working in the open under conditions which are not disgraceful. Therefore the assignment to the road camp may be regarded as a reward, while withdrawal from it and return to the walls is regarded by all prisoners as a severe punishment. By the proper granting and withdrawing of this and other rewards which will be discussed in a succeeding chapter, and only by so doing, can corporal and severe punishment of all descriptions be eliminated.

Against the advantages outlined above, the opponents of road labor urge the following objections:

It exposes the convict to the public gaze and not only advertises his shame, but has a tendency to harden the public feeling by permitting it to grow accustomed to spectacles which constantly suggest crime. This objection is advanced not by sentimentalists only, but by men among the most thoughtful and experienced of prison officials and students of penology in all civilized countries. At the International Prison Congress at Budapest in 1905, where the question of open-air occupation of prisoners was discussed by experts from all nations, the conclusions were summarized in brief form as follows:[1]

> It will be noticed that the Congress has committed itself in favor of working prisoners in the open air as far as possible, but under very rigid conditions and with careful restrictions. It is very dangerous, in introducing a reform, to carry it too far and to break it down by wrong methods. All the best authorities, for example, insist that prisoners working outside the prison ought never to be brought in contact with free

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[1] "Notes on Outdoor Labor for Convicts." Chas. R. Henderson.

laborers and with the general public. They give reasons for this position. If prisoners are set to work on public roads or streets of cities where people are constantly passing, they must be chained and guarded by men armed with deadly weapons. If the weapons are used in places where citizens pass, there is danger of killing the wrong person. Nothing can be more degrading to a prisoner, nothing more hardening to the public feeling, than the public punishment of convicts.

These conclusions carry the weight of the highest authority; but it should be noted that they are directed only against the employment on the roads of that class of prisoners which can be so employed only when secured by chains and armed guards. It is generally conceded that any successful employment of prisoners depends upon their proper classification and the adapting of the labor imposed to the needs and ability of the individual convict; and for those prisoners who can be employed in public under proper conditions road work offers a convenient, productive, and beneficial occupation. It is believed, however, that the foregoing objection is valid when applied to the indiscriminate employment of convicts in public.

The second objection, which also carries force when applied to any system of outdoor labor which does not include a classification or grading of prisoners according to character, habits, and ability, is that the congregate life of the road camp exposes the better convicts to the physical, mental, and moral contamination of their more depraved associates. However, this objection, like the first, is not directed solely against road labor and can not apply to such labor when conducted under proper conditions.

A third objection is to the effect that road labor is not suited to the ability or physical strength of all prisoners, and that there is a class of prisoners, such as physicians, lawyers, merchants, clerks, whose previous habits of life entirely unfit them for such work, who will never apply such manual experience after release and who may receive actual physical injury through such employment. Table 3 shows that this class does not form more than 20 per cent of the entire prison population of any State listed, that in many the proportion is far below that, and that the average for all States included in the table is only about 10 per cent. Therefore, this objection also can apply only to the indiscriminate employment of all prisoners on road work, and can not be held against any system which provides for the careful classification of prisoners and the subjection to road labor of only those who are found to be fitted for such work.

The fourth, a more serious objection to road work than any of the foregoing, is that such work, in common with other forms of outdoor employment, affords much greater opportunity for escape than does any form of indoor employment. To offer this greater opportunity to prisoners weak in self-control is to place before them a temptation they can not well resist; and to subject them to the possibility of being shot if they yield to their uncontrollable impulses, is unfairly to place their lives in jeopardy. However, the seriousness of this objection is minimized by a proper selection of the convicts who are to be detailed to the road work. Under the present generally prevailing system, judges are compelled to impose definite sentences and when such a sentence has been served the prisoner is released regardless of his fitness again to take his place in society. It would seem therefore that the escape of a prisoner thus arbitrarily sentenced may not be much more dangerous than his premature release at the expiration of an irrationally determined period of imprisonment. It must be understood that this is not a criticism of the trial judge, but of the system which requires the imposition of the definite sentence rather than an indeterminate sentence.

A fifth objection is that road work can not prove to be a solution of the prison-labor problem because it is impracticable to provide such employment during the winter. This objection does not apply at all to the employment of prisoners in most of the Southern States, for in those States the climate is sufficiently mild to make road work possible at all times. In the North and West the climate may present a serious obstacle, for it would not be good economy to maintain the additional equipment necessary for the indoor employment of large bodies of men to be used only a few months in the year. But to road work as it can best be used in the Northern States—that is, as an employment for a small number of picked men who are assigned to it as a reward—there can be no greater objection than to farm work or other forms of outdoor industry, and for such small numbers of men work allied to road construction, such as rock crushing and the manufacture of concrete culvert pipe, which can be performed during the winter, may be provided conveniently and at small expense.

The sixth and seventh objections are closely allied with each other. The former is that outdoor employment, particularly on road work involving frequent moving of the men and their camp equipment, entails a larger expense for the maintenance of the prisoners than work conducted within the penitentiary. This objection is frequently pointed out by penitentiary officials upon whom falls the responsibility for the expenditure of prison funds.

The seventh is usually suggested by the highway commissioner or supervisor, who is responsible for the road labor of the convict, and it is that such use of convicts is economically bad, because the same work frequently can be done at less expense by free labor, on account of the comparative inefficiency of the convict labor. Both these objections lose much of their force when it is considered that in some States it is a question not whether the convicts shall be employed on road work or any remunerative work, but rather whether the convicts shall be maintained in idleness or placed upon the roads; while in other States the work done under the State-use system, the only other system which does not conflict directly with the interest of free laborers, is found to be even less efficiently performed than is the road work. Furthermore, except in those sections where the wages of free laborers are exceptionally low or the efficiency of such labor exceptionally high, there seems to be no good reason why road work can not be accomplished by convict labor at considerably less expense than by free labor.

EFFICIENCY AND ECONOMY OF CONVICT LABOR.

The relative efficiency of convicts and free men as road laborers is a phase of the convict problem of particular interest. Unfortunately, it is also a phase upon which it is practically impossible to develop precise information. Manifestly, an entirely fair comparison can be made only where both classes are employed in like localities under exactly similar conditions. This is rarely possible, because convicts and free men are seldom employed together, even on different sections of the same road where conditions might be assumed to be roughly identical, but by making proper allowance for differing conditions it is sometimes possible to form reasonably accurate estimates of the comparative value of the two classes of labor. Estimates of this sort are not wanting, but in their bearing on the general question of the efficiency of convict labor they serve to confuse rather than to illuminate, for they rate the relative efficiency of the convict at from 50 to 150 per cent of that of free labor.

By assembling a number of such estimates from different localities and under different conditions it is possible to arrive at a composite figure which will represent the average relative efficiency of convict labor throughout the localities represented. An estimate of this sort was made by the United States Bureau of Labor and published in the Twentieth Annual Report of the Commissioner of Labor in 1905. The data for that estimate were secured by agents of the Bureau of Labor from prison officials, foremen, contractors, lessees, and from employers of free labor in the localities in which convicts were employed. As a result of this survey, it was found from a total number of 111 estimates in regard to highway construction in the States of California, Connecticut, Florida, Georgia, Kansas, Michigan, Minnesota, Missouri, New Jersey, New Mexico, New York, North Carolina, Oregon, Pennsylvania, South Carolina, Texas, Virginia, Washington, and the District of Columbia, that the labor of 3,522 convicts was equivalent to that of 3,481 free laborers of average skill, working the same number of hours per day. But that such general estimates are of little value in the consideration of particular cases is well illustrated by the fact that if the estimates for the States of California, Connecticut, Kansas, Michigan, Minnesota, New Jersey, New Mexico, New York, Oregon, Pennsylvania, and Washington, in which a majority of the convicts are white, are separated from those for the southeastern States, where the majority of the convicts are negroes, it is found that in the former section 355 convicts were estimated to be equivalent to 174 free laborers, which would indicate a relative efficiency of each convict of only about 49 per cent, whereas in the southern States it was computed that the labor of a daily average number of 3,167 convicts could not have been performed with less than 3,307 free laborers of the same States, indicating that the convicts of that section, under the direction given them, accomplished approximately 5 per cent more than the free laborers.

Because of this extreme variability of the relative efficiency of convict labor and free labor, a study of the causes which bring about a difference in the efficiency of the two would seem to be more profitable than an attempt to indicate by figures the amount of the difference. These causes are of two classes, the first being found in the character of the convicts and free men considered as individuals, and the second in the organization and control of groups of each kind of labor.

Considered as an individual worker, it seems to be generally assumed that the average convict is less efficient than the average free worker. As a class they undoubtedly possess a lower order of intelligence and less initiative, ability, and willingness in the performance of honest work than free laborers. Of course, there are as wide differences in character among convicts as among free men, and many convicts prove themselves to be the equals of the best free laborers. But a larger number, by nature possessed of normal ability, seem to have permitted their faculties to become dulled through long careers of idleness, viciousness, and crime; some are mentally or physically defective, and thus unable to compete on a parity with free labor; and others, abnormally quick and intelligent, are shrewd enough to evolve all sorts of schemes to avoid work which is distasteful to them. While the foregoing remarks are true with respect to convicts as a class, it should be noted that the negro convicts of the South are generally conceded to present an exception to the rule. Other conditions being equal, they are regarded by all those best qualified to judge as more efficient workmen than the available free labor of the same section. The reason for this condition is probably found in the fact that the best classes of negro laborers are not generally obtainable for road work, and that when the negro of criminal tendency falls into the hands of the law he is compelled to live a regular and healthful life, which results in his marked physical improvement, while the fear of punishment produces a respectful attention to the orders of the overseers, and a willingness to do more work than money would induce him to perform.

In certain sections, notably in the South, the convicts are drawn largely from previous occupations involving the performance of a kind of labor similar to that required in road work. On the other hand, prisoners of other sections are derived to a much greater extent from the shops and factories, and far fewer of them from the outdoor occupations. For example, Table 3 shows that in New England and the Middle Atlantic States the average proportion of convicts derived from professional pursuits and from the ranks of the merchants, tradesmen, shop workers, and indoor laborers was 42.8 per cent. The occupations of these men prior to conviction were totally dissimilar to the work of the road camp, and in general they do not make efficient road laborers. In the southern States represented, however, it will be observed that the average proportion of convicts belonging to these same classes was only 16 per cent, the remaining 84 per cent being derived from the class of outdoor laborers to whom road work is more or less familiar, and who are best fitted by nature to perform the hard manual labor which it involves.

The second class of causes explaining this difference between free and convict labor includes those factors in the organization of convicts into working groups, in their discipline, and in the means adopted for effecting their security, some of which tend to promote the efficiency of the convict force as compared with the free-labor gang, and others which tend toward relative inefficiency. It is probable that these factors are more important in determining the efficiency or inefficiency of convict labor than is the factor of individual efficiency.

In comparing the economy of convict and free-labor gangs, consideration must be given to the facts that the daily expense of a convict to the State is much less, as a rule, than the daily wage of free labor, and that even though the convicts be actually less efficient than the free laborers, man for man, it is possible that the work of the convict gang may be more productive than the free-labor force at the same cost. This difference between the cost of maintaining the convict and the wage of the free laborer is the greatest economic advantage of convict labor, and the extent of this advantage in a number of the States is indicated by comparison of columns 9 and 17 of Table 4.

TABLE 4.—*Cost of maintenance of convict labor.*

State or county.	Maintenance costs per calendar day.															
	Food.	Clothing.	Guarding.	Transportation.	Medical attention and incidentals.	Interest and depreciation of camp structures and equipment.	Per diem.	Total.	Force employed in camp maintenance.	Maintenance cost of productive laborers per calendar day.	Time of productive laborers lost by— Sickness.	Time of productive laborers lost by— Sundays and holidays.	Time of productive laborers lost by— Bad weather.	Time of productive laborers lost by— Total.	Maintenance of productive labor per working day.	Daily wage of free labor.
New Jersey:									*Per cent.*		*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*		
State camp No. 1	$0.45	$0.045	$0.433	$0.02	$0.035	$0.124	....	$1.107	14.0	$1.287	5.0	15.0	7.0	27.0	$1.763	$1.75
State camp No. 2	.24	.045	.431	.01	.046	.093	....	.865	7.0	.93	1.0	15.0	7.0	23.0	1.208	1.75
Kalamazoo County, Mich.:[1]																
Married men	.50	.01	....	.005	.015	.02	$1.00	1.55	....	1.55	.5	15.0	7.0	22.5	2.00	2.00
Single men	.50	.01	....	.005	.015	.02	.20	.75	....	.75	.5	15.0	7.0	22.5	.968	2.00
New Mexico	.253	.068	.053	.102	.043	.043	....	.562	10.0	.624	.5	15.0	2.0	17.5	.753	2.00
Arizona:																
Guarded camps	.414	.108	.378	.104	.055	.017	....	1.076	15.0	1.266	3.0	15.0	2.0	20.0	1.582	2.50
Honor camps	.414	.108	....	.104	.055	.017	....	.698	16.0	.831	3.0	15.0	2.0	20.0	1.039	2.50
Colorado	.288	.05	....	.03	.030	.022	....	.42	17.5	.509	.5	15.0	5.0	20.5	.640	2.25
Utah	.25	.05	.45	.07	.03	.03	....	.88	9.0	.967	.5	15.0	4.0	19.5	1.186	2.25
Virginia	.095	.032	.148	.009	.064	.041	....	.389	10.0	.432	3.0	15.0	7.0	25.0	.576	1.25
Texas:																
Smith County honor camp	.315	.019	....	.025	.002	.03	.25	.641	17.1	.772	.5	15.0	6.0	21.5	.983	2.00
New York State camp	.355	.043	.226	.035	.02	.04	....	.719	13.0	.826	5.0	15.0	7.0	27.0	1.131	2.00
Washington:																
Honor camps	.404	.132	....	.06	.035	.04	[1] .50	.671	12.5	.767	6.0	15.0	8.0	29.0	1.58	2.50
South Carolina:																
Charleston County	.122	.04	.213	.02	.044	.025	....	.464	15.0	.546	8.0	15.0	5.0	28.0	.76	.75
Richland County	.179	.04	.385	.01	.03	.02	....	.664	10.0	.738	.5	15.0	5.0	20.5	.928	1.00
Union County	.18	.03	.303	.01	.035	.015	....	.573	8.0	.623	1.0	15.0	5.0	21.0	.788	1.00
North Carolina:																
Durham County	.30	.041	253	.005	.03	.02	....	.649	8.0	.705	1.0	15.0	5.0	21.0	.892	1.25
State Camp	.226	.04	.245	.02	.03	.02	....	.581	10.0	.645	2.0	15.0	5.0	22.0	.827	1.25
Georgia:																
Fulton County	.195	.11	.174	.01	.012	.04	....	.541	8.0	.588	.5	15.0	5.0	20.5	.74	1.50
Chatham County	.112	.053	.22	.01	.043	.04	....	.478	8.0	.52	1.0	15.0	5.0	21.0	.658	1.50
Florida:																
De Soto County	.30	.05	.40	.01	.01	.01	....	.78	8.0	.868	2.0	15.0	5.0	22.0	1.087	1.50
Osceola County	.28	.116	.32	.02	.05	.02	....	.806	6.0	.847	1.0	15.0	5.0	21.0	1.085	1.50
Orange County	.40	.062	.153	.01	.025	.025	....	.675	7.0	.726	2.0	15.0	5.0	22.0	.931	1.50
Alabama:																
Bullock County	.20	.06	.17	.01	.02	.02	....	.48	10.0	.533	1.0	15.0	5.0	21.0	.675	1.00

[1] Per diem paid on working days only.

The only other important economic advantage of convict labor over free labor is that the force is absolutely dependable so far as numbers are concerned. Plans for work can be made in advance with a sure knowledge that the anticipated number of laborers will be on hand to execute them. There can be no tardiness in the convict camp such as is frequently the fault of free labor, and, furthermore, the regularity of the force enables a competent overseer to develop the maximum efficiency of each man to an extent which is not possible with shifting free labor.

But this latter quality which, in one respect is an advantage, in another is one of the most serious defects of convict labor. The constancy which makes the force dependable in attendance and which permits the overseer to provide each man with the work best suited to him, prevents altering the size of the force with changes in the requirements of the work. The force is constant and must be constantly maintained, whether the work justifies it or not. During the delays incident to the failure of road or quarry machinery, the belated arrival of road material, difficulties in acquiring right of way, the opening of new sources of road surfacing material, high water in quarries or gravel pits, and other unavoidable causes too numerous to mention, the whole or a part of the force must be maintained in relative idleness. On Sundays and holidays and during bad weather the continuous expense of the convict camp goes on. In addition to these losses the sick must be maintained though they are entirely unproductive, and this loss amounts to from one to five per cent.

The above concerns the losses in the time of the productive labor of the camp, but part of the squad employed in preparing food and maintaining the camp is necessarily always unproductive in units of road work. The proportion of the force so employed varies from 7 to 17 per cent, and the average is about 10 per cent.

Thus taking into account only the losses which can be anticipated with reasonable accuracy and omitting from consideration those which are incident to unavoidable failures in the work, the cost of maintaining one productive road laborer one working day will be found to be from 40 to 50 per cent greater than the maintenance cost per convict per calendar day. Table 4 contains data secured by representatives of this office relative to the itemized cost of maintenance and the time lost for the above mentioned reasons. In a number of instances the figures given are necessarily estimates because accurate records were not at hand, but it is believed that they are the best estimates obtainable. The effect of the lost time upon the maintenance cost will be apparent at once by comparison of columns 9 and 16.

Aside from the large loss through enforced idleness there are a number of other causes of inefficiency due to the very fact that the laborers are convicts. Among the most important of these is the lack of a sufficient incentive to induce the convict to labor diligently. Even among free laborers the man who works for the pure love of his work is in a decided minority. These thoughts do not animate the convict. He has no fear of losing his position, and he is aware that he will rarely be punished for the small procrastinations which he knows well how to practice. Indeed he is very sure that his guards and keepers expect him to be inefficient in a small way, and that he will not forfeit his good time for any but flagrant violations of the rules or open disobedience to orders. He prefers to work rather than to remain in absolute idleness, but he takes his work as a pastime and seldom permits it to become irksome. He sets his own pace and there is a comparatively small percentage of ambitious workers among convicts, such as set the standard of work for the less ardent among free laborers. He frequently feigns sickness to avoid work, and often in such a way as to defy detection. He becomes surly and unruly when worked beyond his will so that his keepers often are forced to lower their standards, in order to avoid the too frequent administration of punishment. The investigators witnessed an example of this sort in an eastern State, where a squad of convicts engaged in grading was found divided into two gangs of pickers and shovellers respectively. The shovellers rested while the pickers worked, and vice versa, which amounted to the employment of the entire squad only one-half the time. When questioned about this practice the superintendent replied: "It is impossible to work the men economically because they would become dissatisfied and we would have to be sending them back to the penitentiary continually." Corporal punishment is forbidden in this State, hence to administer punishment means to return the men to the penitentiary. Though this is an extreme example, all who have worked convicts know that it is only possible to overwork them by the introduction of actual cruelty into their discipline, and that in general the only men about a convict camp who are likely to be overworked are the foremen and the superintendent.

This lack of incentive may be overcome to a great extent by a system of reward for earnest effort, as explained elsewhere in this bulletin.

Another fact which precludes the possibility of developing the convict squad into as efficient an organization as the free-labor gang is that in the former it is impossible to eliminate completely the incompetent worker. As stated, there are differences in ability among convicts as among free laborers, but whereas in the employment of the latter it is possible, by selection, to raise the plane of efficiency of the organization to a high level, the incompetent convicts generally must be carried along with the relatively competent, and the efficiency of the organization suffers by the presence of diseased and crippled convicts, incapable of performing a man's work, and those who, by reason of idleness or self-indulgence prior to conviction, are physically soft and inexperienced. The presence of these undesirables, from a labor standpoint, seriously hampers the development of an efficient organization.

A further source of inefficiency is frequently found in the difficulty of securing superintendents and foremen who combine the qualities of judgment and tact in the management and control of the convicts, and of skill and ability in road construction. The attempt to avoid this difficulty by the employment of two set of officers frequently is rendered abortive by the creation of friction between the two branches of control. Often the difficulty of securing competent superintendents is increased by the fact that candidates must be acceptable not only from the standpoint of their qualifications as road builders and guards, but also in respect to their political connection, and usually the salaries offered to candidates are so low as not to attract men of a high order of ability. These various difficulties frequently result in the selection of incompetent officials, superintendents, and guards, and such a step is invariably reflected in the low plane of efficiency of the convict force.

Much of the inefficiency of convict work results from the use of guarded convicts upon that type of road, which for its most economical construction requires a very flexible force. The construction of top-soil and sand-clay roads can not be satisfactorily done with gang labor, but requires a force readily divided into small units. In dealing with guarded convicts it has been found that one guard can successfully handle as many as 15 men when the character of the work will permit the organization of squads of that size. Grading, quarrying, and the construction of macadam roads afford such an opportunity, but the less continuous and more widely distributed work on the cheaper road surfaces prevents the use of such large squads. That this factor is of more than mere theoretical interest is evidenced by the records of the Virginia Highway Commission. In this State, where the convict road force is managed as well as in any State in the Union and with a lower maintenance cost than in any other State, the records of the cost of road work during the period from 1909 to 1915, inclusive, as given in Table 5, show that while the work of grading and the construction of macadam roads were conducted to considerable advantage with convict labor, the convicts employed in the building of gravel roads were able to show only a slightly lower cost per mile than free laborers employed on the same class of work, while the average cost of sand-clay and soil roads was nearly 45 per cent higher. These records confirm the opinion of many engineers and foremen that the use of convict labor on the light work ordinarily carried on by the counties of the southern States is a mistake. In the interest of economy it would be better were all this work done by free labor and the use of convicts confined to heavier construction and grading. But if convicts are to be used at all on such work they should, without doubt, be honor men, who may be organized into a fairly mobile force.

TABLE 5.—*Showing comparative mileage and cost of various types of road constructed in Virginia by convicts and by free labor.*

[Based on 12-foot width of surface.]

MACADAM ROAD.

Year.	By convict labor.			By free labor.		
	Miles.	Total cost.	Cost per mile.	Miles.	Total cost.	Cost per mile.
1909	45.41	$203,662.85	$4,484.98	18.26	$89,050.78	$4,876.82
1910	53.52	233,314.57	4,359.39	81.25	401,905.83	4,946.53
1911	56.77	195,671.52	3,446.74	67.90	336,369.88	4,953.90
1912	48.27	218,589.38	4,528.47	95.57	551,475.04	5,770.38
1913	91.11	368,570.96	4,045.34	85.87	484,343.59	5,640.42
1914	69.46	286,655.65	4,126.92	81.13	372,743.46	4,594.40
1915	76.48	303,110.76	3,963.27	82.83	376,761.99	4,494.36
Total average	441.02	1,809,575.69	4,103.16	512.81	2,612,650.57	5,094.77
GRADING.						
1911	1.60	$3,043.30	$1,902.06	71.25	$169,577.77	$2,380.04
1912	24.34	29,946.12	1,230.33	190.23	618,885.49	3,253.35
1913	3.73	4,711.97	1,263.26	94.43	178,547.12	1,890.79
1914	3.32	3,185.82	959.58	141.39	222,454.73	1,573.34
1915	38.09	69,639.04	1,828.28	173.20	291,379.22	1,682.33
Total average	71.08	110,526.25	1,554.95	670.50	1,480,844.33	2,208.57
GRAVEL ROAD.						
1909	25.20	$32,289.37	$1,281.32	8.86	$11,539.82	$1,302.46
1910	32.50	39,433.40	1,213.33	49.94	61,066.18	1,222.78
1911	25.69	29,454.37	1,146.53	66.68	85,098.10	1,276.22
1912	7.89	11,708.11	1,483.92	59.74	75,475.23	1,263.40
1913	55.05	67,556.69	1,227.19	64.13	80,780.97	1,259.64
1914	45.51	74,659.92	1,640.51	71.85	128,801.69	1,792.65
1915	22.60	41,419.38	1,832.71	103.96	221,083.36	2,126.62
Total average	214.44	296,521.24	1,382.77	425.16	663,845.35	1,561.40
SAND-CLAY AND SOIL ROAD.						
1909	16.91	$5,251.48	$310.55	49.57	$24,463.59	$493.52
1910	24.96	17,613.08	705.65	111.01	48,290.23	435.01
1911	39.92	28,080.65	703.42	174.97	69,629.81	397.95
1912	90.21	53,811.71	596.51	195.37	83,638.53	428.11
1913	101.44	69,314.40	683.30	345.60	169,492.43	490.43
1914	218.90	148,161.87	676.85	479.34	251,676.08	525.04
1915	174.33	153,064.83	878.02	408.94	227,344.16	555.93
Total average	666.67	477,298.02	715.94	1,764.80	874,534.83	495.54

Another very important factor in determining the economy of a convict force is the population of the camp and its adjustment to the work to be done, but it is a factor which is overlooked frequently, with resulting inefficiency and failure. Among the considerations entering into the determination of the most effective size of camp are the character of the work, the size of squad that can be safely handled by a guard or foreman, the number of camp men necessary to prepare food and keep the camp in order, and the nature and convenience of the camp buildings and equipment. A camp whose only operation is grading should not be so large as one which is designed to carry along the grading of a road, quarrying and crushing stone, and surfacing all at the same time; but whatever the work, the size of the camp should be properly proportioned to it, and if the working force be too great or too small inefficiency is sure to follow. Also, it is evident that if one guard or foreman can safely control 10 convicts, a working force composed of any number of men not a multiple of 10 is to a certain extent an uneconomical force, since in that case one guard would have a squad of less than 10. Not less than two men are required to cook and care for even the smallest camp, and no more than two are required for 20 men. Furthermore, the overhead charges for superintendence, engineering, and bookkeeping are but little if any larger for 40 or 50 men than for 20, and the per capita cost of these items decreases as the population increases. The maximum limit is reached with the largest population for which the superintendent can assume responsibility successfully. Between the minimum and maximum limits the most effective population, in any case must be determined by trial and observation; but it is likely that under average conditions this will be found to be about 40 or 50 men. In many of the smaller southern counties the number of convicts on hand at one time is not more than 20 who must be employed either inefficiently on the roads, or at some less desirable occupation, or else maintained in idleness. Under the present laws in many of the States this condition must be endured, but it might be remedied by the enactment of laws placing county convicts under State control and employment.

Finally, the employment of short-term men invariably results in ineffective work. Since to harden and instruct the recruit requires, in the qualified judgment of superintendents and foremen, from 30 to 60 days, it is obvious that road work employing misdemeanants of terms averaging less than six months must bear a heavy burden of lost time and ineffective labor.

The foregoing are the principal factors which determine the relative efficiency of convict and free labor. They form a body of conflicting and opposing tendencies the individual weight of which can not be appraised except by study and trial in the particular case at hand. In this statement lies the reason for the continuance of inefficiency in all convict work. For, though the tendencies outlined in this chapter have been well known, the means of studying the comparative influence of each under particular conditions have not been at hand, owing to the failure of public authorities to preserve adequate record of the amount and cost of work performed and the exact cost of the maintenance of convicts. Because of the apparent cheapness with which convicts are fed, clothed, and housed, officials have been led, through this lack of adequate records, into a false sense of security in regard to the economy of convict labor, and there has been a tendency to condone and overlook lapses from a standard of high efficiency because of a feeling that the margin between the daily cost of convict and free labor was wide enough to allow a certain amount of waste. But a comparison of the costs of maintenance of convicts and the prevailing wages of free labor in the typical cases given in Table 4 should prove convincingly the need of closer attention to detail in the employment of convicts.

In considering the economic improvement of a system of convict road labor the geographical factor must be kept in mind constantly. The problem in the South is widely different from that of the North, East, and West, and there are minor differences between the conditions in these latter sections. In the South, the human material dealt with is so radically different from that of the other sections that its problems are not to be remedied by means which will apply very well to the other sections. But, as has been shown, the difference is economically in favor of the South because of the character of the previous experience of its prisoners, their greater responsiveness to discipline, and the relative cheapness of their accustomed manner of living. However, in general, it is believed that the interests of economy may be subserved—

First, by strict attention to the cost of maintenance and by honest effort to reduce it to the minimum amount consistent with proper living conditions and discipline; second, by the reduction, so far as possible, of all losses of working time; third, by providing a positive incentive to industry to offset the negative fear of punishment; fourth, by the elimination of politics as a factor in the selection of officials; fifth, by offering to officials such salaries as to command the services of capable men; sixth, by combining the responsibility and authority for the direction of road work and convicts in one person at each camp; seventh, by such a diversification of labor and employment as to provide for the large body of prisoners the kind of work in the performance of which they manifest the greatest ability; eighth, by judicious selection of the work to be performed by convicts; ninth, by the proper adjustment of the size of the force to the requirements of the work and by the formation of camps of economical size; tenth, by adopting a more mechanical kind of work for short-term prisoners, or, if they must be employed at road work, the separation of long and short term men.

As has been stated, it is exceedingly difficult to secure reliable cost data on the employment of convicts, but after a wide study of the convict problem throughout the United States the following examples of accurate and authoritative information have been selected from a mass of generalities and superficial statements. They present reliable comparisons of the efficiency and economy of the two kinds of labor employed on the same roads in different sections of the United States.

Example I. From September, 1913, until August 26, 1914, guarded convicts were employed under the supervision of the State highway engineer on the Bisbee-Tombstone highway in Arizona. On the latter date the convicts were withdrawn from the work in order to provide employment for free labor thrown out of work by the condition of the copper industry which followed immediately after the opening of the European war. The free labor employed to continue the work consisted, therefore, largely of copper miners, and was paid at the rate of $3 per eight-hour day. A comparison of the work done by convicts during the month of July, 1914, and that done by free labor on the same road during September of the same year, both forces being employed under the same general superintendence, shows a marked advantage in the use of the convict labor. The daily average number of prisoners actually employed in the road work in July was 77, and the daily average number of free laborers actually employed during September was 71. A comparison of the various items in Table 6 will show not only that the work was done by the convicts at lower unit costs, which might be attributed to the extremely high price of free labor, but the actual amount of work accomplished per individual in the same time was greater in the case of the convicts than of the free men.

TABLE 6.—*Comparison of free and prison labor on Bisbee-Tombstone road, Arizona.*

Activity.	July, prison labor.			September, free labor.		
	Total quantities.	Quantities per man.	Unit price.	Total quantities.	Quantities per man.	Unit price.
Grading:	*Cubic yards.*	*Cubic yards.*		*Cubic yards.*	*Cubic yards.*	
Solid rock	1,649.7	21.42	$1.375	981.6	13.82	$2.13
Loose rock	961.3	12.48	.59	521.6	7.34	1.515
Bowlders	829.8	10.78	.81	937.9	13.21	1.777
Excavation:						
Solid rock	389.5	5.06	1.23	219.1	3.09	2.676
Loose rock	21.5	.28	1.16	3.0	.04	1.666
Concrete	143.4	1.86	6.0	65.0	.91	9.44
Masonry	44.4	.58	5.46	37.0	.52	6.53
Ditching:						
Solid rock	84.1	1.09	1.52	21.7	.31	2.64
Earth	39.8	.52	.46	53.0	.75	.925
Clearing and grubbing	[1] 7.0	[1] .09	11.31	[1] 3.0	[1] .04	11.87

[1] Acres.

Example II. The effect of a large amount of lost time upon the cost of work by convict labor is very apparent in Table 7 of unit costs of work performed in the State of Washington by honor convicts, free day labor, and contract labor on the Olympic, Pacific, and other highways. In explanation of the results accomplished with convict labor the biennial report of the State highway commissioner is quoted as follows with regard to the Olympic highway work:

> The excavation work during the winter months was entirely in earth. The earth, which is classified as common excavation, is a material composed of a mixture of soil and gravel, resting on a cemented gravel or hardpan foundation, which slopes toward the road and water's edge. Owing to the porous nature of the soil and the impervious foundation below, a large amount of surface water is retained, thus causing many slides. During the winter months these slides were a continual source of expense. Great quantities of soft earth intermingled with trees, stumps, and brush would come down on the road, and in some instances destroy the finished roadbed. When the conditions would permit, the men worked even though it rained, with comparatively little ill-feeling toward their position. At times the material became so soft that it would run from the shovels and resemble mortar more than earth and the men sank halfway to their knees in the mire. During the month of January it rained continuously for 25 out of 27 days and working under such unfavorable conditions, the best of efforts accomplished but little, much time necessarily being lost * * *.

And in regard to the Pacific highway work:

> About the same general conditions surrounded this work as that on the Olympic highway, but the excavation was in a different class of material and the slides did not interfere with the progress of the work. Over half of the excavated material was solid rock and could be handled more economically during the wet weather than the earth.

TABLE 7.—*Unit costs of work on certain highways in the State of Washington.*

Items of work.	Convict labor.		Day labor.			Contract labor.			
	Olympic highway.	Pacific highway.	Olympic highway.	Pacific highway.	National park highway.	Olympic highway.	Olympic highway.	Sunset highway.	McClellan pass highway.
Common excavation, cubic yards	$0.446	$0.304	$ 0.21	$0.38	$0.226	$0.31	$0.325	$0.28	$0.35
Loose rock excavation, cubic yards	.645	.559	.37	.50	.857	.45	.50	.48	.40
Solid rock excavation, cubic yards	1.02	.933	.83	.94	....	1.50	.90	.88	1.00
Clearing, acres	110.18	112.43	92.44	61.10	126.44	200.00	75.00	150.00	175.00
Grubbing, acres	174.20	155.67	113.44	87.10	257.29	300.00	110.00	150.00	150.00

On the other hand, it is stated that the contract and free day-labor work was conducted only during the summer when weather conditions were favorable. As a further aid to the intelligent comparison of the data in Table 7, it is stated that the prevailing cost of free labor was $2.50 per eight-hour day, and of a double team and driver $5 per eight-hour day, whereas the equivalent cost of the convict's labor was approximately $1.58 per day as shown in Table 4.

Example III. During the months of November and December, 1913, certain work was performed by convicts at State camp No. 2, in New Jersey, which at prevailing contract prices, as given by the engineer in charge, would have cost as follows:

Earth excavation, 4,700 cubic yards, at 45 cents per cubic yard	$2,115.00
80 acres removed at $4 each	320.00
Grubbing 0.22 acre at $75 per acre	16.50
Fence removed, 4,600 feet, at 6½ cents per foot	299.00
Hedges replanted, 200 feet, at 20 cents per foot	40.00
Total	2,791.50

The actual cost of the maintenance of the camp during the two months in which the above quantities were accomplished was as follows:

Rent of camp grounds	$20.00
Coal	84.53
Feeding men, guards, and superintendents	602.57
Guarding	648.54
Team hire	573.75
Dynamite	64.25
Tobacco, medicine, telephone, and gasoline	208.04
Interest at 6 per cent and depreciation at 10 per cent per year on buildings and furnishings valued at $3,066.69	81.77
Interest at 6 per cent on $1,022, cost of well	10.22
Interest at 6 per cent and depreciation at 75 per cent a year on hand tools valued at $449.90	60.73
Supervision	850.00
Total	3,204.40

In the above costs the interest and depreciation on machinery, which was valued at $12,734.78 in the list of cost items, has been omitted, as probably little of it was used on the work performed during the two months under observation. But omitting this item it appears by a comparison of the two totals given above that the cost of the work by convict labor was $412.90 greater than it would have been had it been performed by contract.

MANAGEMENT AND OPERATION.

All prisoners employed at road work in the United States are termed either State convicts or county convicts, according to the political subdivision, whether State or county, by which they are convicted and imprisoned. The employment of county convicts on roads is rare in the North but common in the South; in fact, the earliest employment of convicts in this manner in the United States was by the southern counties, and the numbers of their convict road forces still greatly exceed those employed in a similar manner by the States.

County control, therefore, has been thoroughly tested and the experience has revealed a number of inherent faults which render it ineffective for the fullest realization of the benefits of convict labor. In the main it has been productive of waste and inefficiency for the reason that the average county force is economically too small, and much of the work done is, perforce, of a very inconsequential nature. In many counties the entire time of the inadequate force must be spent in the attempt, by small repairs and patchwork, to keep the roads in barely passable condition. This inefficiency is generally recognized and deplored by county officials, but it is usually defended by the assertion that the only alternative under the existing system is to maintain the convicts in absolute idleness, which could not be justified on any ground.

Another serious objection which may be pointed out in connection with county control is the lack of coordinated effort which is typical of the independent operations of the numerous counties. As these objections are similar to those which have been responsible for concentration of supervision of construction in the State highway departments, there can be no doubt that similar control in the management of convict labor would effect a great improvement.

Such an arrangement is provided for in Virginia under the law of 1906, which established the State convict road force. In addition to the State convicts, this State force also includes all male county jail prisoners over 16 years of age, and the latter class, as well as the former, is subject to any assignment within the State, which the superintendent of the penitentiary may direct. The apportionment of the county convicts among the various counties may be determined according to population, road mileage, property values, or any other equitable criteria which may be fixed under particular conditions; but, however the distribution be made, the results of the creation of such a State force will be the same, namely:

(1) That the total overhead expense for the administration of all the convict labor of the State will be reduced by the elimination of a large number of small offices and the consolidation of the supervision in one central office;

(2) That the wider outlook of State officials will lead to the practical adoption of more scientific methods;

(3) That the greater financial means of the State will permit of the employment of a more able class of officials;

(4) That the counties will be relieved of the expense of maintaining small convict forces which produce inconsequential results;

(5) And that the force of convicts will be available for work in the counties where there is a demand for the heavy road work best suited to the employment of convict labor, while slight repairs and maintenance not economically done with convict labor may be performed by free labor, supplemented, perhaps, by small forces of paroled convicts.

Although the superior advantages of State over county control are very evident, the placing of the control in the proper State department is more difficult. On account of the dual aspects of the work—the penal and the constructional—the interests of two departments are involved—namely, the prison and highway.

In Colorado the work is carried on under the immediate direction of the warden of the State penitentiary, and the State highway commission acts only in an advisory capacity. In Georgia there is no highway commission, and the convict road work is carried on by the various counties, the conditions affecting the convicts being under the control and inspection of the State prison commission. But in all other States in which there are highway departments the road work done by the convicts is under the direction and control of the highway authorities, and the prison departments exercise only a more or less direct control over the discipline, guarding, and maintenance of the prisoners.

Though it is recognized that no stereotyped system of control can be prescribed arbitrarily for all the States, on account of their varying institutions and customs, it is believed that the best results may be obtained under a system which clearly defines and separates the responsibilities of the prison and highway departments. The prison department should, of course, be charged with the selection of convicts for assignment to the road working forces, upon the request of the highway department, and with the formulation of rules and regulations for the guidance of the highway officials in the discipline, housing, and maintenance of the prisoners. But the supervision of construction and the preparation of adequate means of housing, feeding, and disciplining the men in accordance with the rules of the prison department preferably should be under the immediate control of the highway department. By such an arrangement the formation of a highway division under the prison department, with consequent duplication of officers, is avoided, while, as indicated, the prison department, through the agency of the highway department, retains control of the administration of the penal law.

By the foregoing arrangement the responsibility of the distribution of the convict labor to the various pieces of construction is given to the highway department. The labor may be used on State roads, or it may be granted to the counties as a form of State aid, but in either case full control of the work and conditions of work should be exercised by the highway department to insure the essential uniformity of methods and results. Although a certain amount of discretionary authority must be given to the men in immediate charge at the camps, they should be governed by regulations and orders issued by the department. Their conduct of the work should be ascertained by means of periodical reports made in a prescribed form to the highway department, and by frequent visits of inspection by officers of the highway department, the prison department, and, in States where such a bureau exists, by officers of the State board of health, who should report, through their bureau, on the sanitary conditions of the camps.

CAMP OFFICERS.

Though the experience of a number of States has demonstrated the practicability of cooperation by the prison and highway departments through their central offices, the dual system of management in the camps has not proved satisfactory. Prompted by a recognition of the duplex nature of the project, at least three States have tried the plan of placing two men, representatives of the prison and highway departments, respectively, in more or less independent charge of the two phases of the work. In each case the arrangement has resulted in the development of friction and bickering between the employees of the two departments, caused by the clashing of their respective interests and instructions. As a rule, most of the differences are trivial and when brought to the attention of the superior officers of the departments they are readily adjusted, but before these officials are appealed to it is found that the discord has usually reached such proportions as seriously to affect the proper management of the camp. As an example of the petty nature of these disputes it was found in one State that the camp sergeant, or head guard representing the prison department, had been instructed to keep all the convicts at work at all times, except Sundays and holidays, unless prevented by sickness or bad weather. The resident engineer, representing the highway department, had been instructed not to lay surfacing stone on a wet clay subgrade. A dispute arose over the question of the employment of the convicts on days following heavy rains when the subgrade was still wet, the sergeant wishing to send the men to work and the resident engineer refusing to permit any stone to be laid, and the bitter feeling which resulted had practically paralyzed the work of the camp long before the matter was brought to the attention of the heads of the two departments.

But while the appointment of two more or less independent camp heads is undoubtedly inadvisable, it is true that it is extremely difficult to secure, within the customary limits of salary attaching to such positions, one man who is capable of superintending both features of the work. It would seem that the difficulty may best be overcome by providing two officers, but by making one subordinate to the other. It is suggested that the superintendent, or first officer, be selected primarily for his knowledge of road building and for his skill in the direction of men, and that an assistant, who may be known as a camp officer or yard man, be appointed on a basis of skill or experience in the handling of prisoners. The camp officer should be expected to advise the superintendent in matters of discipline and to assume entire charge of the management of the camp proper under the general supervision of the superintendent. It will be found usually that the camp officer will be able to act as a commissary officer and camp clerk, ordering and distributing food and supplies and keeping the camp records, in addition to his other duties.

In the guarded camps two sets of officers, namely, guards and foremen, may be necessary to work under the two principal officers. In such cases, the ratio of guards to convicts should be not less than 1 to 10 and the foremen should be employed in the number necessary for the successful prosecution of the road work, usually 2 or 3 for camps of 40 men. In a number of States there is a tendency to combine the duties of guarding and supervision of the work in one set of officers and when only the less dangerous of guarded convicts are used on road work, as proposed under the scheme of grading as suggested on page 63, this practice would seem entirely safe and proper. But when all classes of criminals are employed regardless of character, it would seem that the evident necessity of avoiding the close approach of convicts to armed guards would render the guards of little value as foremen.

In the honor camps the guards may, of course, be dispensed with and the unarmed foremen, in no greater numbers than are necessary in the guarded camps, will be able to direct the work and also to carry out such disciplinary measures as are necessary.

In all camps, whether of the guarded or honor types, at least one night guard should be provided. In the guarded camps this officer is necessarily armed with a shot gun or rifle, and measures should be adopted to prevent the close approach of the convicts to him in the quarters at night. When the men are chained in the quarters no other protection is necessary, but when they are permitted freedom of movement within the quarters the night guard should be separated from them by a partition, containing a window or opening through which he may command the entire dormitory.

In the honor camps, as a general rule, the night guard should not be armed as there is little chance of preventing a general uprising should such an act be planned by the convicts, and in the event of an attack on the guard it is highly desirable to prevent the capture of arms.

The importance of the selection of men of good character and intelligence to fill the positions of officers and guards has been pointed out so often and is so generally understood as to require little emphasis. Unfortunately, however, the wages usually offered in connection with these positions are not sufficiently large to attract first-class men, and it is believed that there is still much room throughout the country for improvement in this respect. The salaries necessary to attract good men will, of course, vary in the different sections of the country, but experience has shown that the payment of a reasonably good salary to a good man is invariably a better investment than a poor salary paid to an incompetent one. And it should be remembered that competence in a convict camp officer means not only efficiency in road construction, but also self-restraint, moderation, honesty, sobriety, and firmness of character.

To complete the organization of the camp, a certain number of convict helpers under the direction of the camp officer or yard man are necessary to perform the various duties of cooking, cleaning, laundering, etc. Even in guarded camps, it is necessary that such men be trusted to a considerable degree, and they should therefore be selected with this in mind. As to their further qualifications, it is very desirable that the cook shall have had some previous experience, but no special aptitude is required in the other helpers, and in fact it will usually be possible to select for such work convicts of inferior physique, whom it is impossible to employ in any other way. The size of the camp force must be varied with the population of the camp. No less than two men will be required for the smallest camps, and for camps of over 20, one camp assistant should be added for every 10 men up to camps of about 100. In camps of populations greater than 100, the proportion of camp help to total numbers may be somewhat reduced.

RECORDS AND COST ACCOUNTS.

FINANCIAL.

In the conduct of a business involving manufacture or construction, it is a well recognized fact that the standard or primary books of an accounting system should be supplemented by certain subsidiary records known as cost accounts. The journal and the ledger are well designed to preserve a record of transactions to show the total amounts of receipts and disbursements and the balance between them, but they do not enable the manufacturer or constructor to analyze the costs of his products. To supply this need, cost accounts have been extensively adopted in private business, and comparatively recently the example set by private business has been followed in certain branches of public work, such as the water and street departments of municipalities and many of the State road commissions. But though such accounts are particularly useful in the development of unstandardized work of a constructive character, and for this reason should be of the greatest usefulness in the conduct of work by convict labor, the study made by this office revealed the fact that, with few exceptions, only the ordinary journal and ledger accounts are kept. This failure to keep adequate cost accounts is responsible for the extreme paucity of reliable information with regard to the economy of convict labor, and it is needless to say that if practices and methods are to be much improved, a reform of procedure in this direction is vitally necessary. To this end it is proposed to state in detail the reasons for the introduction of cost accounting and reliable personal records, and to indicate the general form which a system of such records and accounts should take.

Briefly, the specific purposes which a system of accounts should serve are as follows:

(1) To make proper account, for the information of the public, and especially the appropriating body, of the total expenditure of funds. This function is more or less adequately served by such simple systems of accounts as are in general use. But though this is the only function of accounting that is generally recognized, it is really the least important of the services which a properly designed system can be made to yield.

(2) More important in the present beclouded state of the question is the value of records and accounts indicating whether convict labor is being employed at a profit. This function can be served only by the introduction of cost accounts which make it possible to analyze the total cost in such a way as to indicate the cost of each process and of the results in detail. It is undoubtedly true that convict labor is conducted at considerable advantage in numbers of instances, but it is also an established fact, that lacking such information, many communities unwittingly employ convict labor disadvantageously, and are daily paying more for such labor than it would have been necessary to pay for free labor.

(3) In addition to indicating what may be termed the "total economy" of convict labor, cost accounts also furnish a means of checking what may be termed "internal economy." A system of convict labor may be, as a whole, economical with respect to free labor, and still there may exist many sources of waste and inefficiency in the system which, if remedied, would make for even greater economy. Such elements of weakness are to be found in unintelligent supervision, improper distribution of labor, wastefulness in the handling of material and supplies, and unreasonable losses of time. In many cases it is only necessary to know of these weaknesses to remedy them, yet they may well escape attention if only general results are known. Furthermore, it is to be observed that such a detailed record of cost kept daily indicates to date the existence of faults and affords the opportunity to correct, in its incipiency, any tendency to overrun proper costs.

(4) An adequate system involving a subdivision of cost accounts provides the means of recognizing merit and of detecting and eliminat-

ing personal inefficiency, and is thus a constant incentive to foremen and superintendents to reduce costs.

With this understanding of the functions which a system of convict labor accounts should perform, it is possible to formulate certain general principles to govern the character of the record forms and methods of procedure necessary to serve these functions. Their precise character can be determined only for the particular conditions under which they are to be employed, and even under special conditions it is practically impossible to outline a system completely in advance, for the reason that details of the work to be accounted for are constantly changing.

The inadequacy of the ordinary methods of double-entry bookkeeping to accomplish the desired ends has already been mentioned. This becomes more clearly apparent when it is realized that those methods were designed primarily for the balancing of receipts and expenditures, whereas the conduct of convict labor work involves disbursements only; and of these disbursements it is desirable to know not only the total amount, but an analysis showing the purposes for which they were made and the costs of the various parts or units of the road work or other work which results in large measure indirectly from them.

Specifically it is important to analyze all disbursements in such manner as to show:

1. The daily and total itemized costs of maintaining the convicts.
2. The unit and total costs of the work.

With regard to the former, the elements of maintenance cost which should be recognized and segregated in a good system of accounts are those chargeable to (*a*) subsistence, (*b*) clothing, (*c*) quarters, (*d*) furniture and equipment, (*e*) kitchen and mess supplies, (*f*) fuel and light, (*g*) medicine and medical attention, (*h*) transportation of convicts and equipment, (*i*) wages of convicts (money, tobacco, discharge clothing), (*j*) miscellaneous, (*k*) guarding or convict supervision.

It is only by such a division of the cost of maintenance that it is possible to determine the exact cause of excessive total costs.

The segregation of the elements is accomplished by opening accounts to each, then classifying and distributing all disbursements among these accounts. The latter should be so kept that at all times it may be possible to determine not only what expenditures have been made and for what purposes, but also the total amount of previous disbursements for each purpose, the amounts of materials received into and issued from the general store or commissary, and the number of individuals (convicts, officers, and visitors) sharing in the use of materials and services. In this way it is possible to determine at suitable intervals the amount of disbursements per individual for each purpose during the latest period, the comparison of these disbursements with those of other periods, and also to maintain a continuous inventory of the stock of material supplies on hand.

The per capita cost of maintenance per calendar day being thus developed, the second set of accounts is necessary to determine the unit and total costs of work. The cost of maintenance per individual work day, which is equivalent to the cost per calendar day corrected for unproductive labor and lost time, should be treated as the wage of labor, and should figure in the cost of construction. In addition there must be a careful record of wages directly paid to officers and hired employees, of the cost of teams used on construction work, of materials consumed in the construction, of depreciation of tools and machinery employed, and of the amount and proper allocation of what are known as overhead expenses. All of these items entering into the cost of the work should be properly accredited to the particular operations and parts of the work to which they are applied. For example, the records should be complete enough to show in the case of the construction of a macadam road not only the total cost of the road, but also the itemized cost of clearing and grubbing, grading, quarrying rock, crushing rock, spreading surfacing material, rolling, etc. The keeping of such records implies the determination of the amounts of the various kinds of work, such as the cubic yardage of earthwork, the square yardage of surface, the area cleared and grubbed in acres, etc. Without such a determination of the amount of work done any system of cost accounting is valueless as an aid in the improvement of methods of work.

The accounts comprised under the above classification are necessary for the determination of unit costs of maintenance and construction. In addition to these, certain operating forms are necessary, such as the usual forms of requisition and order blanks and inventory sheets, and a system of books suitable for recording the business incident to the work. These may consist of the old form of journal and ledger, or more suitably of a system of voucher files and records to replace the ledger.

In the design of the forms to serve the various purposes outlined above it is essential to bear in mind not only what information it is desired to record, but also the desirability of presenting that information in logical and orderly manner and of so regulating and standardizing the size of sheets as to permit of their convenient use and proper filing in a systematic manner. Large forms are cumbersome, and irregular sizes are difficult to file properly.

Forms 1 to 12 represent a series of report and record forms designed in accordance with the above principles. They are presented as concrete examples to illustrate the technical methods of securing the desirable information. It is not expected that they will meet entirely the requirements of any particular system, but it is believed that they are correct in principle, and with suitable modifications can be readily adapted to the use of any State or county convict-labor system. All may be printed on sheets of paper of the following standard sizes: 8 by 10½ inches, 8 by 12½ inches, and 16 by 12½ inches. All but the form for the monthly report of construction (No. 9) have the 8-inch dimension in common, and the maximum length is 12½ inches. The monthly construction report folded once conforms to the 8 by 12½ inch size, so that all forms can be filed in a standard filing cabinet with drawers to accommodate the 8 by 12½ inch size.

Requisition Form.

Form No. 1 is a requisition blank to be made out monthly or weekly by the superintendent, sergeant, or deputy warden in charge of a convict camp and forwarded to the central office from which purchases are made. In order to supply the purchasing officer with sufficient information to determine the necessity of the articles requisitioned, the columns headed "Quantity issued last month" and "Quantity on hand" are included. Space is provided for the signature of the principal camp officer and for the approving signature of his superior officer, the warden or official in charge. In the last column space is provided for the notation by the purchasing officer of the numbers of the orders made out for the various articles requisitioned.

Purchase Order Form.

Form No. 2 is an order blank suitable for use in connection with the preceding requisition form. This form should be made in triplicate, on paper of three colors, one copy to be mailed to the contracting firm or other firm in a position to supply the items desired, one to be retained at the central office, and the third to be sent to the camp for which the order is made. The form is largely self-explanatory, but particular attention is directed to the space provided for the number of the related requisition, the name or number of the camp initiating the order, and the full instructions for the shipment of the goods and the mailing of the bill. The last column in the body of the form is provided for use when goods are bought on contract, for the designation of the articles ordered by contract and item numbers.

Voucher for Supplies and Services Furnished.

Form No. 3 is designed to avoid the multiplicity of sizes and forms of billheads furnished by the various firms and supply houses. The advantage of such a form, designed to fit the filing cabinets in use, and its effectiveness in preventing confusion, inconvenience, and loss will be appreciated by all who have had to deal with large numbers of bills of numerous shapes and sizes. Two copies of the blank form should be mailed with the order to the supply house, and the merchant should be requested to submit his bill on one, retaining the other for his own files if he so desires. The bill should be rendered first to the camp superintendent at the time the goods are shipped. The superintendent should check it against the camp copy of the order and the goods received and certify in the proper place on the voucher form to the correctness of the bill, or make such notations with regard to its incorrectness as may seem necessary. He should then forward it to the central office, where, after it has received the approval of the principal in charge, it may be forwarded through the regular channels for payment. Special attention is directed to the space on the form for the related purchase-order number, the name of the camp for which the goods are purchased, and also the column for contract reference or authority similar to that on the purchase-order form. The purpose of the other columns will be readily understood, the last column being provided for the notation of the accounts to which the items are charged, this column to be used only by the clerk at the central office. Below the columnar section of the form are the sections for the formal certifications of the merchant and the camp superintendent, for the approval of the warden or superior central officer, and for the notation of the date of payment and the number of the check by which payment is made. The instructions to be printed on the reverse side of the form, which are referred to in the note in the upper section, are as follows:

INSTRUCTIONS.

1. Separate vouchers must be rendered for articles and services requested on different orders.
2. This form, when properly filled, is to be sent to the camp to which articles are shipped or for which the service is rendered.
3. When supplies have been furnished upon contract, accepted proposal, or written agreement, upon emergency or special order, reference to the contract or authority should be made in the column headed "Contract reference or authority."
4. Payee should not write in the last column, headed "Account."

For keeping these forms it will be found convenient to provide a vertical file divided into two compartments, one for unpaid and one for paid bills. As they are received from the camps the vouchers can be filed alphabetically in the compartment for unpaid bills and allowed to remain there until paid, when they can be given serial numbers and filed numerically in the other compartment as paid vouchers.

Book Forms.

The book forms for the office record of the transactions of the convict department will not be treated in this bulletin, as it is necessary that they be designed with special reference to the financial practice of each particular institution, and a sample form would be of little assistance. The matter has received attention, however, and the Office of Public Roads and Rural Engineering is prepared to furnish assistance upon application for the design of such forms for particular conditions.

INVENTORY OF PROPERTY.

The inventory form (No. 4) is designed for use in connection with the periodical determination of the value of camp property. In general, it is believed to be self-explanatory, but the column headed "Date received here" is included so as to provide for the keeping of the date of reception of property transferred from another camp.

COST-ACCOUNT FORMS.

All the forms previously described are in the nature of operating forms—that is, they are necessary for the systematic conduct of the financial transactions involved in the management and administration of convict camps. The forms to be described hereafter (Nos. 5 to 9) are designed expressly for cost accounting. They are intended for use as reports from the principal camp official to the central office and copies should be retained at the camp. The information which they contain can originate only at the camp, and they are of primary importance to those in direct charge of the convict labor, presenting, as they do, at regular intervals an accurate representation of the amount and value of work performed.

RATION-REPORT FORMS.

These forms (Nos. 5 and 6) are designed to furnish a check on the daily disbursement of food, a monthly statement of the cost of food, and a continuous inventory of the amount of food on hand.

The food item report sheet, Form No. 5, furnishes detailed information with regard to the daily use of each item of food, such as beef, pork, beans, peas, molasses, coffee, etc., and each item used at any time in the month must be represented by an item sheet in the food report for the month. Thus, if 30 separate articles of food be served in the month, the month's food report will include 30 item sheets. Beginning in the upper right-hand section with the amount of the particular food item on hand at the beginning of the month, space is provided in the column below for the entry of the amounts of the item received during the month at various times, the sum of these amounts and that on hand at the beginning of the month yielding the total which must be accounted for at the end of the month. In the horizontal section of the report are the spaces for the daily entry of the amounts of food issued to convicts and officers and any amounts wasted on account of deterioration or spoiling (not table waste). At the end of the month the sum of the totals of food issued to convicts and officers and that wasted shows the total amount of food issued during the month as determined by the daily weighing. This amount subtracted from the amount above in the total column will give the amount of food which should be on hand at the end of the month. An inventory then is to be taken and the amount actually on hand entered in the space provided. This amount may differ from that which should be on hand according to the record of daily distribution on account of cumulative errors in weighing and loss in weight by drying of the stock during the month. Whatever the difference indicated, it should be added to the total amount wasted and the result should be divided in proportion to the total amounts issued to convicts and officers and used to adjust those totals, the results being entered in the space provided. If the food used during the month has been purchased at more than one unit cost, the separate unit costs should be weighted in proportion to the amounts purchased at each cost and the result should be entered as the average unit cost in the space provided, and in case food of different quality is bought for convicts and officers, respectively, two spaces are provided for the entry of the two average unit costs. The final process in preparing the item sheet is to determine the total cost of the food item used during the month by convicts and officers by multiplying the amounts used by the average unit costs. The space for "Remarks" is added for the explanation of irregularities and for furnishing the specific information required by the note printed on the report.

The summary sheet, Form No. 6, is to be used for the daily entry of the numbers of convicts and officers fed. At the end of the month the total number of visitor-food days may be added and the record of the number of food days will be complete. The other section of the report is to be used at the end of the month for summarizing the total quantities and total costs of food as taken from the various item sheets. By dividing the total cost of the convicts' food by the total number of convict-food days the daily cost of food per convict is obtained, and space is provided for the entry of the result. Similarly, the unit cost of officers' food is obtained by dividing the total cost by the total of officer-food days plus the number of visitor-food days.

REPORT OF SERVICES AND SUPPLIES OTHER THAN FOOD.

The report of services and supplies other than food (Form No. 7) is designed to supplement the ration report and complete the record of maintenance costs. To accomplish this, an account should first be opened to each of the recognized elements of cost. Then one of Form No. 7 should be used for the monthly report of all articles and services purchased under each account. Thus, if articles or services are purchased under all ten of the accounts which the form is designed to cover, the monthly report would be composed of ten sheets of the form, one for each account. In order to reduce the cost under a given account to a cost per capita per day, which is the main purpose of the form, it is necessary that the sum of the actual value of all services rendered during a particular period, plus the actual value of supplies completely consumed or used during the period, plus the estimated depreciation of articles of supply and equipment not completely consumed during the period, shall be divided by the number of convict days for the period. The depreciation of articles not entirely consumed can be determined only by means of an inventory. But as the depreciation of many articles is very slight in a period of a month, it is impractical to take the inventory at less than six-month periods.

In inaugurating the system of accounting, a complete inventory of all goods should be taken, and the ascertained value of all supplies and equipment of a given class on hand should be placed in a space provided at the head of the total column on the proper account form. Subsequently, during the first month, all items purchased should be reported, giving the names of the items, the dates of purchase, the quantities, and their unit and total costs. At the end of the first month the total cost of the items purchased should be added to the original inventory value to obtain the grand total of value invested in the camp at the end of the month. At the beginning of the second month the latter figure should be placed at the head of the total column. Entries of the items purchased during this month should be made as during the first month, and all operations should be similarly repeated every month.

When a period of six months or a year has elapsed, the grand total of the last monthly report will represent the total amount invested in the camp under the given account since the beginning of the period. An inventory taken at this time will show the approximate value of all articles of supply and equipment remaining in use or in stock, and this value deducted from the grand total of the last monthly report will give the value of the goods and services consumed or used during the period as nearly as can be ascertained. If this value be divided by the total number of convict-days for the period, which a proper use of the form will show in the upper right-hand corner, the result will be the daily per capita cost of supplies and equipment used under the given account during the period. This figure, added to the daily per capita cost of food for the various months, will give the true cost of maintenance per convict per calendar day for each of those months. Finally, to obtain the true cost of maintenance per convict per working day, this latter value must be modified on account of the time lost by Sundays, holidays, camp duty, and sickness, all of which losses are reported on the daily reports of construction (No. 8).

The distribution of charges to the various accounts is largely a matter of judgment, but the classification of items given under the heading "Clothing, camp supplies, and equipment" (p. 152) will serve to indicate the general scope of the accounts.

DAILY REPORT OF CONSTRUCTION.

Form No. 8 is suggested for the daily report of construction. In addition to the name, date, weather, and other lines which form the heading, there are spaces for reporting the amount and kind of all labor, such as superintendence, hired labor, teams, and convicts, the wages per day, and the subdivision of the time of each kind of labor among a number of work accounts, such as rock, loose rock, and earth excavation, and quarrying and crushing rock. There are also spaces for reporting the amount of time lost by reason of bad weather, Sundays and holidays, sickness, and camp duty, and for the total time of each kind of labor. In the second section of the report there is provision for the daily report of materials of construction used in kind, amount, and cost, and for charging such materials to their proper work account. Finally, by means of the progress report at the bottom of the sheet, the locality and kind of the day's work may be shown and also the locality and length of the finished work. The form is designed as a daily report for the reason that the information it should convey can only be accurately recorded daily, while the operations of the day are fresh in the minds of the officials.

MONTHLY REPORT OF CONSTRUCTION.

The last of the cost-account reports is shown as Form No. 9, namely, the monthly report of construction. The report is designed for the monthly summary of the information contained on the daily reports of construction, and for the purpose of completing and reducing that information to useful form. One sheet should be made out to the account of each class of work done during the month, and the entries of the time of each kind of labor employed should be made on the proper date lines each day, at the same time that the daily report is made out. At the end of the month the total number of days served by each kind of labor on a given class of work will be shown by the sums of the daily time entries in the spaces provided for "Total days." Below the latter spaces are others for reporting the daily wage and board of each kind of free labor, and for the sum of the two, which represents the total daily rate. Multiplying "Total days" by "Total rate" in each case gives the "Total amount," or cost of each kind of labor for the month. The daily rate in the case of convict labor is the daily per capita cost of maintenance, and this can not be determined each month on account of the long life of some of the items of supplies and equipment. However, for the purpose of month to month comparisons of work costs, it is permissible to assume a convenient figure to represent the daily rate, and on the basis of this assumed rate to compute an assumed amount or cost. Then the sum of the total amounts for all kinds of free labor and the assumed amount for the convicts will give a total "Assumed labor cost" which should be inserted in the proper space in the "Table of unit costs" at the bottom of the sheet.

In the "Materials used" section the quantities, rates, and costs of the various materials used during the month on the given class of work should be summarized from the daily reports of construction; and the total cost of materials thus determined should be inserted in the space provided in the "Table of unit costs." The results of the monthly estimate of work done being also entered in their proper spaces of this section of the report, as indicated, it is possible to compute an approximate unit cost of the work which will be comparable with a cost ascertained in a similar manner for other months, though it will not be the actual unit cost of the work on account of the use of the assumed convict-labor cost. When the actual daily per capita cost of maintenance is made available by the determination of the cost of supplies and equipment, at intervals of six months or a year, the actual unit cost of the work may be determined and the record may be made true and complete.

PERSONAL RECORDS.

The records, accounts, and forms discussed in the foregoing paragraphs all have to do with the economic phase of convict labor, and, as that is a very important aspect of the problem but one which has been much beclouded by hasty judgment and misleading information, their utility as an aid in forming accurate estimates of the value of work performed can hardly be too strongly emphasized. Of equal importance, however, to the complete history of a system of convict labor are the so-called personal records of the convicts, having to do with the manner of employment of individuals, receipts and discharges of prisoners, pardons, punishments, escapes and recaptures, sickness and deaths. Unlike the cost accounts, the importance of these records is very generally recognized, and as a rule the systems in use are entirely adequate.

Examples of the more important of these are shown by Forms Nos. 10 to 12, and it is believed that their purpose and the manner of their use will be so apparent as to require no explanation. Other forms of this character, examples of which are not shown, but which may be added if desired, are those for recording punishments administered, money and valuables held for convicts, and any particular phases of the work necessary to record.

The personal reports shown correspond in size to the cost account reports and may be filed in drawers of the same size.

FILING SYSTEM.

A very convenient method of filing the cost-account and personal reports is to inclose all the reports for one month in a manila envelope of proper size, on the back of which may be printed a blank summary form for the display of the significant figures of all the inclosed reports. The envelopes for the various months and camps may then be filed in order in a simple drawer letter file.

Numbering of Forms.

Instead of designating the various forms by their names, which may be rather cumbersome, it is a good plan to give each of the reports a form number. The sample forms shown are numbered according to a decimal system, by which the numbers serve to designate not only the individual forms but also the class of forms to which they belong. For example, the forms shown are divided into four classes according to their use, as follows:

Class I. Operating forms, including (1) Requisition; (2) Purchase order; (3) Voucher for supplies and services furnished; (4) Inventory of property.

Class II. Maintenance reports, including (1) Food-item report; (2) Summary of quantities and cost of food issued; (3) Report of services and supplies other than food.

Class III. Work reports, including (1) Daily report of construction; (2) Monthly report of construction.

Class IV. Personal reports, including (1) Prisoners' time sheet; (2) Movement of prisoners; (3) Daily report of sickness.

All forms of Class I have in their numbers the figure 1 on the left of the decimal point, and the four forms in the class are numbered from 1 to 4, respectively, on the right of the decimal point in the order in which they are enumerated above. The three forms of Class II are designated by the figure 2 on the left of the decimal point, and the figures 1 to 3 in the order of enumeration above, on the right of the point; and the numbers of forms in Class III and Class IV are determined in like manner.

Form No. 1.1.

.... CONVICT ROAD FORCE.
(*Name of County or State.*)

REQUISITION.

Requisition No. ......
Supplies to be sent to ....
(*Place.*)
Not later than ...., 191..
Camp No. ......
Date of Requisition ...., 191..

Quantity.	Article.	Quantity issued last month (or week).	Quantity on hand.	Order number.
				(Not to be filled by Supt.)

I certify that the quantities on hand and issued are correctly reported, the above articles are required, and the quantities are not excessive.

Approved: ...., Warden. ...., Supt.

1. Use different colored sheets for requisitions for food supplies and general supplies.
2. Whenever an emergency purchase is made locally, fill out this requisition form covering the purchase, write the word "Emergency" on it and mail it with the bill to the warden.
3. If the article is unusual explain the need for it on the requisition.

FORM 1. SIZE, 8 BY 10½ INCHES.

Form No. 1.2.

................................, CONVICT ROAD FORCE.
(*Name of County or State.*)

PURCHASE ORDER.

Order No. ......
To Fill Requisition No. ......
From Camp No. ....
................................, ..., 191..
(*Name of city or town.*)
Firm name ....
Address ....
Please ship the following articles to ....,
...., via ....,
and render the bill on the inclosed voucher form to ....
....
Signature ....
(*Purchasing Agent or Official in Charge.*)

Quantity.	Name of article.	Contract reference.

FORM 2. SIZE, 8 BY 10½ INCHES.

Form No. 1.3. Voucher No........

..............................CONVICT ROAD FORCE.
(*Name of County or State.*)

VOUCHERS FOR SUPPLIES AND SERVICES FURNISHED.

Date, ..., 191..

....
(*Name of County or State.*)

To..Dr.

Goods supplied on

Purchase Order No...... Address..

For Camp No...... ....

(Consult instructions on other side before preparing voucher.)

Contract reference or authority.	Articles or service.	Quantity.	Unit.	Unit price.	Amount.		(Leave blank.)
					Dollars.	Cts.	Account.

I certify that the above bill is correct and just, and that payment therefor has not been received.

(Payee sign here)..............................

Title....................................

I certify that the above articles have been received by me in good condition and in the quality and quantity specified, or that the services were performed as stated.

Signature..Supt.

Approved for $ Signature.....................................Warden.

Paid by check No......, dated............................., 191...

FORM 3. SIZE, 8 BY 10½ INCHES.

Form No. 1.4 Sheet No......

..................................CONVICT ROAD FORCE.
(*Name of County or State.*)

INVENTORY OF PROPERTY.

Camp No........ Place...................................., Date................., 191..

Listed by..

Quantity.	Item.	Description (Dimensions, materials, etc.).	Date of purchase.	Date received here.	Original value.	Present value.	Condition.
				Totals,			

FORM 4. SIZE, 8 BY 10½ INCHES.

Form No. 2.1.

.... CONVICT ROAD FORCE.
(*Name of County or State.*)

Ration report.

Month of ....
Camp No. ....
Place ....
Signature ....
Supt.

Food Item ....
Usual Ration ....

On hand first of month ....
Received during month. (Give date of receipt and unit cost of each shipment.)

Total to be accounted for ....

Issued to—		2	3	4	5	6	7	8		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Convicts																																
Officers																																
Waste																																
Total issued.																																

Remarks: (State cause of waste; make statement of amount of food donated and raised, and give dates and manner of use. Food received but later returned should be deducted from amount received during month, and reason for return stated below.)

Should be on hand at end of month ....
Inventory at end of month ....
Adjusted total issued to convicts ....
Adjusted total issued to officers ....
Average unit cost of food used by convicts ....
Average unit cost of food used by officers ....
Total cost of convicts' food ....
Total cost of officers' food ....

FORM 5. SIZE, 8 BY $12\frac{1}{2}$ INCHES.

Form No. 2.2.

................................, CONVICT ROAD FORCE.
(*Name of County or State.*)

SUMMARY OF QUANTITIES AND COSTS OF FOOD ISSUED.

Month of ....

Camp No. .... Place .... Supt.

Item.	Quantity.		Unit.	Unit cost.	Total cost.		Days.	Number persons fed.	
	Con.	Off.			Convicts.	Officers.		Convicts.	Officers.
							1		
							2		
							3		
							4		
							5		
							6		
							7		
							8		
							9		
							10		
							11		
							12		
							13		
							14		
							15		
							16		
							17		
							18		
							19		
							20		
							21		
							22		
							23		
							24		
							25		
							26		
							27		
							28		
							29		
							30		
							31		
							Number of visitor-food days.		
							Daily cost of food.		
							Per convict.		Per officer.
Grand total cost....									

FORM 6. SIZE, 8 BY 12½ INCHES.

Form 2.3.

.... CONVICT ROAD FORCE.
(*Name of County or State.*)

REPORT OF SERVICES AND SUPPLIES OTHER THAN FOOD.

Camp No. ....
Place ....
Signature .... *Supt.*

Account ....
Month of ...., 191..
Number of convict days since last inventory to first of month.
....
Number of convict days this month ....
Total number of convict days to date ....

Date.	Item.	Last inventory value plus subsequent purchases to first of month			$
		Purchased during month.			
		Quantity.	Unit cost.	Total cost.	
	Total for month....................................				$
	Grand total..				$

FORM 7. SIZE, 8 BY 12½ INCHES.

Form No. 3.1.

....

(*Name of County or State.*)

CONVICT ROAD FORCE.

DAILY REPORT OF CONSTRUCTION.

Name of camp ....
Name of place ....
Name of road ....
Kind of road ....
Date ....
Weather ....
Name of supt. ....

FORCE REPORT.

	Title.	Rate per day.	Effective labor days.																		Lost labor days.				Total.
			Rock excavation.	Loose rock excavation.	Earth excavation.	Excavation for culverts and bridges.	Laying pipe.	Mixing and placing concrete.	Quarrying rock.	Crushing rock.	Loosening surface.	Loading surface material.	Hauling surface material.	Spreading surface material.	Sprinkling.	Rolling.	Mixing sand-clay.	Dragging.	Clearing and grubbing.	General.	Bad weather.	Sundays and holidays.	Sick.	Camp duty.	
Superintendence.																									
Hired labor.																									
Convicts.																									
Teams.																									

REPORT OF MATERIALS USED.

Item.	Quantity.	Rate.	Amount.	Account.

PROGRESS REPORT.

Activity.	Worked to-day.		Completed.	
	Station to station.		Station to station.	

FORM 8. SIZE, 8 BY 10½ INCHES.

Form No. 3.2.

....CONVICT ROAD FORCE.
(*Name of County or State.*)

REPORT OF CONSTRUCTION.

Account......................................., Month of......................., 191..

Name of road..............Kind of road............Camp No...Place............Signature..............

Date.	Superintendence.				Hired labor								Teams.		Convict labor.
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
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21															
22															
23															
24															
25															
26															
27															
28															
29															
30															
31															
Total days,															
Wage															Assumed rate.
Board															Assumed amount.
Total rate															Actual rate.
Total amount															Actual amount.

MATERIALS USED.

Item.	Quantity.	Rate.	Cost.	Item.	Quantity.	Rate.	Cost.
Carried forward,				Total cost,			

TABLE OF UNIT COSTS.

Activity.	Quantity.	Units.	Total cost materials.	Assumed labor cost.	Actual labor cost.	Approximate unit cost.	Actual unit cost.	Unit.

FORM 9. SIZE, 12½ BY 16 INCHES.

Form No. 4.1.

.... CONVICT ROAD FORCE.
(*Name of County or State.*)

PRISONERS' TIME SHEET.

Camp No. .... Place, ... Month of ...., 191..

Signature, ..., Supt.

Prison No.	Name.	Days on road.	Days camp duty.	Days bad weather.	Days of sickness.	Days, Sundays and holidays.	Total number days.
	Total carried forward	....	....	....	....	....	....

FORM 10. SIZE, 8 BY 10½ INCHES.

Form No. 4.2.

.................................., CONVICT ROAD FORCE.
(*Name of County or State.*)

MOVEMENT OF PRISONERS.

Camp No. ...... Place, ... Month of ...., 191..

Signature, ..., Supt

On hand first day of month ....
Received during month ....
Recaptured and returned during month ....
To be accounted for ....
Discharged ....
Pardoned or paroled ....
Died ....
Escaped during month, and still at large ....
Sent to ....
....
....
Convicts on hand at end of month ....
Total (should agree with total above) ....
Remarks:

FORM 11. SIZE, 8 BY 10½ INCHES.

Form No. 4.3.

.... CONVICT ROAD FORCE.
(*Name of County or State.*)

DAILY REPORT OF SICKNESS.

Number of camp ....
Place ....
Date of illness ....
Day of illness (as 1st, 2d, 3d, etc.) ....
Name of convict ....
Of what does the convict complain? ....
What signs of sickness did he show to-day? ....
What treatment was given to-day? ....
Was he seen by the doctor to-day? ....
Doctor's diagnosis to-day ....
Signature of superintendent ....

FORM 12. SIZE, 8 BY 10½ INCHES.

DISCIPLINE AND METHODS OF CONTROL.

As stated elsewhere in this bulletin, one of the most serious objections to the employment of convicts on road work or other form of outdoor labor is that such employment invariably presents greater opportunity for escape than any work conducted entirely within walls. When the work is well conducted this disadvantage is outweighed by more favorable considerations, but it is generally accepted that every effort should be made to reduce the number of escapes to a minimum, and in order to accomplish this, the system of discipline and methods of securing the prisoners must be well adapted to the special conditions of the work and the particular character of the convicts.

Until a few years ago all convicts employed in the open were restrained by armed guards and chains and were distinguished from free citizens by suits of striped material and, frequently, by shaven heads. This system of discipline will, for the sake of distinction in the following discussion, be termed the "guard system." Lately, however, there has been developed another plan under which the security of the convict is placed largely in his own hands, and this is popularly known as the "honor system." A number of State wardens have inaugurated work under this system with much apparent success, and the more enthusiastic of its supporters advocate its general adoption by all the States. But conservative officials hesitate to attach value to a system which depends so largely upon what they believe to be the questionable honor of a convict. In the controversy that has arisen between the adherents of the two systems, much misunderstanding and confusion has resulted from a failure on the part of each group to understand the aims and purposes of the other, and by an erroneous belief in the sufficiency of one system or the other.

In the attempt to clear up this confusion the principal methods of discipline practiced under each system are briefly described herein, with reference to the most noticeable limitations and advantages of each.

THE GUARD SYSTEM.

This system of discipline is practiced in one form or another in connection with road work in the States of Alabama, Arizona, California, Delaware, Florida, Georgia, Kentucky, Louisiana, Missouri, Minnesota, Mississippi, New Jersey, New York, North Carolina, North Dakota, Oregon, South Carolina, Tennessee, Texas, Utah, and Virginia.

In its most rigorous form it is practiced in the southeastern States of Alabama, Florida, Georgia, North and South Carolina and Virginia. Here prisoners while at work in the open are under the constant surveillance of guards armed with double-barreled or repeating shot guns and revolvers, the ratio of the number of guards to the number of convicts varying from 1 to 8 to 1 to 15. In all except Virginia the guards also act as foremen in charge of the road work; in the latter State they are given no authority over the work of the convicts, but confine their attention to the guarding of the prisoners, and the distance which they are required to maintain between themselves and the prisoners to prevent surprise or attack renders them practically valueless as foremen. Convicts who are regarded as particularly dangerous or likely to escape are shackled during the day with leg chains of various forms intended to limit the stride and prevent running; and occasional instances of the use of the ball and chain, principally as a punishment for attempted escape, are still to be found. As a rule, all convicts, regardless of character, are clad in striped uniforms, though Georgia has adopted a plan by which they are divided into three grades, according to conduct and character, and prisoners of the first two grades are no longer required to wear stripes. In Virginia jail prisoners employed on the roads by the State highway commission are dressed in brown. For securing and housing the convicts at night steel or wooden cages on wheels are extensively employed in all the States except Virginia, but tents and cheaply constructed shacks also are used, and permanent stockades are provided in a few counties. In Virginia the camp structures are practically uniform in character, and consist of light shelters constructed with metal roofs and canvas sides. In these latter structures and in the tents and shacks of other States, the convicts are generally secured by means of their individual leg chains to a long continuous chain, the two ends of which are locked, and in addition to these measures one or more night guards, armed in the same manner as the day guards, are usually provided. It is the common practice to employ the prisoners on the roads throughout the daylight hours, all hands being marched to the work in squads under armed guard as early as practicable after sunrise and returned to camp in the same manner just before dark. But little opportunity for recreation is provided, though a few sergeants, superintendents, or wardens, as the overseers are variously called, permit indulgence in outdoor games on Saturday afternoons and Sundays. Invariably, however, convicts are kept within the camp limits at all times except while at work and the general practice is to keep them "on the chain" or in their cages on Sundays and holidays. Privileges are limited to the infrequent reception of visiting relatives, the writing of occasional letters, and the issuance of the weekly ration of tobacco. As a general rule, all prisoners are accorded the same treatment, though in all camps a few prisoners of the better sort, those with short terms, those who are bound to the neighborhood of the camp by family ties, or those who for any reason are unlikely to attempt to escape, are appointed as "trusties."

These positions are created to meet certain requirements of the work where guarding is impracticable, as in the case of men who may be used in the positions of drivers, waterboys, or camp men but whose discipline differs but little from that of the "gunmen," aside from their assignment to somewhat lighter and more agreeable tasks. The trusties in these southern camps comprise from 5 to 50 per cent of the total population, the average ratio being about 20 per cent.

Except in so far as it involves compulsory labor and regularity of life, the system of discipline, as practiced in this section, is not reformatory. In a number of camps provision is made for religious instruction by the employment of a minister to make weekly or monthly visits to the camps, but, in general, the convicts depend for such instruction upon the negro preachers who are found frequently among their number. In practically all camps the races are separated by providing separate sleeping quarters, or at least by the segregation of each race in different sections of the same structure, and at meals, also, the races are segregated.

In a few camps, negro women are employed as cooks and camp helpers, but this practice is condemned by the large majority of officials. Whipping is practically the only form of punishment administered. In all of the States of this section the authority to administer such punishment is reposed only in the superintendent or chief camp officer, and the number of lashes which may be inflicted at one time is restricted by law in some States. The lash is usually applied to the bare back, though this practice is forbidden in the States of Florida and Georgia. Good behavior and satisfactory labor are rewarded by the granting of "good time" in all the Southern States, with the exception of Alabama. Such deductions from the legal sentence vary in the different States; thus in South Carolina the allowance is 1 month per year; in North Carolina 5 days per month; in Georgia, county misdemeanants are allowed 4 days per month, while State felons who have attained the first grade may be paroled at the termination of their minimum sentence; in Florida the amount of the deduction is graduated from 2 days to 10 days per month for the first 9 years and 15 days per month for the tenth and all succeeding years. Bloodhounds are kept in a majority of the southern camps for use in the recapture of prisoners who attempt to escape, and it is believed by those who use them that their mere presence exercises a salutary effect.

The foregoing are the principal features of the most rigorous form of the guard system. In some States, notably in New Jersey, New York, Oregon, Arizona, and Utah, many of these features have been modified materially without abolishing the system in its entirety. In all these States the use of striped clothing has been entirely discontinued, and the result of the change is regarded as a success.

Shackles of all kinds also have been discarded. Though in the three western States named the guards are armed with revolvers and rifles and are about as numerous in proportion to the convicts as in the southeastern States, in New Jersey and New York the guards carry only concealed revolvers and each one is responsible for the security of 20 or 30 convicts. In these States, and the North and West generally, the convict cage and the night chain are not tolerated by public opinion, and apparently the same degree of security is obtained instead by the use of stockades, substantial buildings, and night guards.

In the road camps of Utah, where tents are used exclusively, a high degree of perfection in the prevention of escapes has been attained without the use of chains. The tents are pitched within a square of approximately 150-foot dimensions, the limits of which are marked by a single-strand wire fence. At two diagonally opposite corners of the inclosure and immediately outside the fence are two small guard tents, and the only opening in the fence is near one of these tents. Situated at the corners, each of these guard stations commands a clear view of two sides of the inclosure, and guards are on duty at each station at all times when the convicts are in camp. At each of the guard corners are two strong locomotive headlights, so directed as to illuminate the two sides guarded from the respective corners. Convicts are forbidden to enter or leave the inclosure except by way of the single entrance and they are cautioned on pain of punishment not to approach the fence at other points, while at night no excuse is considered sufficient to justify a convict in approaching the fence at any point without permission. Working under this arrangement with a force of men maintained at approximately 70 for three years up to November 1, 1914, there had been only one escape, a record which hardly could have been improved upon had every man been chained night and day.

In all the States of this group convicts assigned to road work are selected especially with reference to their moral character and their general fitness for the work. The discipline of the road camp is markedly less severe than that of the prison from which they are removed, and eight or nine hours of labor is the rule. More or less latitude is allowed the prisoners in the employment of their time after working hours, games, periodicals, and books being provided for use between supper and the retiring hour, which is, as a rule, about 9 p. m. In New Jersey and New York particular attention is paid to this matter, and baseball games and other outdoor sports are arranged regularly during the season for Saturday afternoons. Whipping is not permitted, and the only punishments which are sanctioned are deprivation of meals, and return to the penitentiary, except that in Arizona prisoners may be punished for minor infractions of camp rules by confinement, on short rations, at the camp in a wooden jail or lockhouse. In this group of States convicts assigned to the road camps receive an allowance of "good time," under provisions of law similar to those already mentioned as applying in the Southeastern States. But in Utah the special character and labor of the road men is recognized by granting to them an additional deduction amounting to four months for each year of service on the roads. By reason of the fact that the road men in these States are especially selected for the work, all are regarded as equally trustworthy, and "trusties," as the term is used in the southern camps, are not selected, but such positions as drivers and water boys may be filled almost indiscriminately from the camp population. While blood hounds are not used, every effort is made to recapture escaped convicts by means of widely distributed advertisements and rewards, and the penalty for attempted escape is return to the penitentiary upon recapture, with the loss of all credits in "good time" and the loss of the larger privileges of the camps.

In all sections there is a decided feeling among prison and camp officials that free laborers should not be employed in conjunction with the convicts, but in a number of instances free men have been employed as drivers, roller engineers, steam-shovel operators, dynamiters, and in other positions necessitating the employment of skilled labor. Every effort is made to limit the intercourse of such employees with the convicts in order to prevent the introduction of intoxicating liquors, morphine, and opium into the camps, and in some States the act of furnishing a convict with any of these liquors or drugs constitutes a legal offense punishable by fine or imprisonment.

THE HONOR SYSTEM.

This system of convict discipline originated in the West. From the best information obtainable it was practiced to a limited extent in Montana as early as 1894, but it did not attract general notice until more than 10 years later, when it was adopted by Colorado and New Mexico. Following the lead of these States it has since been adopted and practiced, to a greater or less extent, in connection with road work in the States of Arizona, Idaho, Illinois, Michigan, North Carolina, Nevada, Oklahoma, Oregon, Texas, Washington, West Virginia, Wisconsin, and Wyoming, and it is possible that in connection with other work it has been practiced in some of the other States. It is adaptable to the government of only a part of any convict population, and in all the above States convicts assigned to work under it have been confined previously in the State penitentiaries, where they have been under observation for a sufficient length of time to make a character determination possible. After such a period of probation, however, the prison officials of the States which have adopted the system find that it is possible to so employ from 10 to 50 per cent of their respective prison populations, the proportion varying somewhat according to the character of prisoners dealt with, the proportion employed in the majority of States being from 20 to 25 per cent. Under this system, as its name implies, much dependence is placed in the honor of the convict; but it should not be supposed that prisoners are worked under it absolutely without guard, for though the superintendents and foremen are not armed and are responsible for from 15 to 30 convicts each, instead of 10 or 15, as under the guard system, they are, nevertheless, able to make their surveillance practically as close as is usually thought to be necessary in the case of the trusties of the guarded camps. Furthermore, it is found that the men themselves, realizing that the liberties and privileges of all are dependent upon the conduct of individuals, will go a long way toward regulating their own conduct and preventing escapes. With the exception that not even concealed weapons are carried by the officers of the honor camps, the discipline is very similar to that in the camps conducted under the modified form of the guard system as practiced in New Jersey and New York. As in the camps of those States, the uniform of the men is not particularly distinctive, there is no whipping, no chaining, no employment of bloodhounds, and the order of the camps is largely dependent on the granting and withdrawal of privileges and not upon the imposition of positive punishment. The inducements which are held out for good behavior and faithful work are:

A more liberal reduction in sentence than that granted to other prisoners. This usually amounts to from 5 to 10 days per month, in addition to the regular or statutory good time.

The freedom of the vicinity of the camps after working hours.

Permission to indulge in baseball games, quoits, and other outdoor sports in the evening.

Occasional visits singly, in groups, or in a body to a near-by town, and occasional attendance at a theater or entertainment.

Very liberal mail privileges.

Better food than the guarded convicts receive.

In a few States, the payment of a cash per diem.

Furthermore, when, as usually is the case, the honor system is employed in connection with the indeterminate sentence, convicts assigned to road work may be given the opportunity of parole at the expiration of the minimum sentence or shortly thereafter.

Punishment is effected by the withdrawal, either temporary or complete, of any or all the above privileges, and under the indeterminate sentence the offending inmate may be required to serve the maximum sentence for his offense. However, it is the invariable rule wherever the honor system is practiced that serious infractions of the rules shall be followed by immediate return of the offender to the penitentiary, where the prescribed punishment is administered.

In two States, Washington and Texas, the honor system is applied only to conditionally paroled convicts, who are required to enter into "honor agreements" or contracts with the governors of the States, in which they promise to work faithfully and well under the conditions prescribed, either until given final release, as in Washington, or for a specified period of a year, as in Texas. In the former State, a cash per diem of 50 cents is paid and in the latter a similar per diem of 25 cents is granted under the terms of the contracts. In both these States, however, the disciplinary measures effective in the camps are in all essentials the same as in other States.

COMPARISON OF THE GUARD AND HONOR SYSTEMS.

The guard system may be adopted effectively, as it has been in the South, for the discipline of convicts of all classes. The honor system, on the other hand, is applicable only to a selected number of any prison population, and can not, with safety, be indiscriminately applied. However, in maintaining the security of those prisoners who are employed under them, the two systems appear to be equally effective, as will be noted by comparison of the following percentages of escape reported from a number of States using each system. In the road camps of New York and Utah, the number of convicts who escaped in 1914 formed less than one-half of 1 per cent of the total number of individuals handled; in New Jersey the proportion was 2.5 per cent; in Virginia 3.5 per cent; and in the counties of North Carolina, South Carolina, Georgia, and Florida the percentage varied from 1 to 6. All the foregoing States employ some form of the guard system, yet the percentages of escapes sustained are roughly the same as in the following States, which employ the honor system in their road camps: Oklahoma, 1 per cent; Colorado, 1.2 per cent; Kalamazoo County, Mich., 2 per cent; New Mexico, 3 per cent; Washington, 3.5 per cent, and Montana, 5 per cent. It will appear by examination of the above statistics that the lowest proportions of escapes were registered in the States of New York and Utah, in which a modified form of the guard system is applied to a selected group of convicts; but it should be stated that in the Southern States in which the convicts are employed indiscriminately under the guard system with its chain gang, the majority of escapes occur in the trusty class. It is urged in favor of the guard system in the Southern States that under it large numbers of convicts have for some time been safely employed at work on the roads; that their work has been largely productive in the construction of many miles of improved highways, and that during the time they have been thus employed the States have been relieved of the burden of maintaining expensive penal institutions. Under no other system of discipline would it have been possible to have employed such large numbers of convicts in this way. But aside from these alleged economic advantages very little can be said in favor of the chain gang and the system of discipline which alone renders it possible. It comprises no conscious reformative measures, and except for the fact that it provides compulsory and regular outdoor labor for a class of individuals who are habitually averse to it, it can show no reformative results. It entails the exposure of the convicts, subjects them to unnecessarily severe punishments, and, except in the South, is not tolerated by public sentiment. The economic advantages in the form of the road work performed which are urged in justification of the discipline are doubtful, but this phase of the problem has been taken up in detail under the topic of economics. The modified forms of the guard system practiced in New York, New Jersey, and Utah are not open to such serious objections, but except for the fact that the guards in these States are armed either with concealed or exposed weapons, the discipline in these States embodies many of the characteristics of the honor system.

The honor system, discriminately applied, is shown by the statistics given above to be fully as effective as the guard system in preventing the escape of the convicts worked under it; and from the standpoint of the peace and security of the community, the escaped "honor convict" is likely to be less dangerous than the prisoners who escape from a guarded camp, for the very reason that the former is presumably of higher moral character than the latter.

Judged upon an economic basis, the honor system should result in some lowering of cost, although part of the saving through dispensing with guards is expended in supplying the convicts with conveniences and comforts not usually furnished under the guard system. Furthermore, the honor convicts may be more efficiently distributed than is practicable under the guard system.

The selection of prisoners for such employment under the honor system is a task requiring the greatest judgment and care, as well as experience in the study of criminal character. Full consideration should be given to the history of the individual prisoner prior to conviction, his habits and associates, the character of his offense, the circumstances surrounding its commission, and his traits of character as observed during the probationary term of close confinement, which should not only be long enough to make an intelligent choice possible, but also to impress upon the convict the necessity of subordinating his will and desires to those of others.

No hard and fast rules can be given to govern the selection of honor men. A few prison officials believe that it is safe to trust only prisoners with relatively short terms, arguing that the temptation to escape is almost irresistible to the man who has the prospect of a long term of imprisonment to face. Yet the experience of the majority of officials is that the long-term man is not much more likely to attempt escape than the short-term man, and there are on record innumerable instances of the escape of prisoners with only a few days left to serve, whereas "lifers" are to be found serving faithfully and well in many honor camps. The character of the offense committed is considered by some officials in the selection of their honor men, preference being given usually to prisoners convicted of impulsive crimes where it can be found that the commission of the criminal act was surrounded by extenuating circumstances. Many prisoners serving sentences for murder, manslaughter, assault, and grand larceny are found to be absolutely trustworthy when placed on honor. But, in general, there is considerable hesitancy in trusting to the honor of the sneak thief, the pickpocket, the burglar, or any prisoner convicted of a petty crime against property.

The physical environment in which the convict will be placed on honor also should exercise an influence upon the selection of the honor men. The presence of a city or town near the honor camp calls for the use of greater discrimination in the selection of the camp inmates than is necessary in manning a camp which is located remote from a center of population. The trusted convict should not be subjected to temptation greater than he is capable of withstanding. Therefore, in proportion as the location of the camp affords greater or less opportunity for escape a higher or lower standard of trustworthiness must be set for its inmates.

That the honor system can not be applied successfully to negroes is asserted by many experienced prison officials. Their opinions are based upon long experience with negro character and its peculiarities. They point out that the majority of attempts to escape from the southern chain gangs are made by negro trusties. However, the positions of the chain-gang trusty and the honor man are not comparable. It has been already stated that the former is trusted as a matter of convenience only. Off the work he is accorded much the same treatment and is governed by the same rigorous discipline as the "gunmen." On the other hand, when the honor man returns to camp after his day's work is done he is accorded many small liberties and privileges which have the effect of convincing him that he is in fact, as well as in name, a trusted man, and tend to promote his self-respect and the desire to merit the respect of others, in addition to rendering the lure of the free life around him a little less hard to resist. That the negro criminal may be safely employed under the honor system has fortunately been demonstrated by actual experience in a number of States. In Colorado and the other Western States, though they naturally form only a small percentage of the populations of the camps, the negroes are not noticeably less amenable to the discipline than the whites. In West Virginia, where the system has been in operation since 1913, and where more than half of the convicts employed under it are negroes, it is reported that of 18 attempts to escape made in 1914, 16 were by white men and only 2 by negroes. But the most convincing proof of the amenability of negro prisoners to honor-system discipline is that which is being recorded daily in the experimental convict camp established by the commissioners of Fulton County, Ga., in cooperation with the Office of Public Roads and Rural Engineering. At this camp, established in January, 1916, with a population of 40 negro convicts drawn from the guarded camps of the county, not a single attempt to escape has been reported in the seven months during which it has been in operation. Whipping as a punishment has been entirely abandoned, and the foremen in charge of the men are entirely unarmed, yet the discipline is satisfactory in every respect and the industry of the inmates is above the average. Inasmuch as it is conceded by all persons of experience in dealing with convicts that the most dangerous period in the life of an honor camp is that immediately after its inauguration, the results of this experiment in the heart of the South must carry considerable weight as evidence of the fitness of the negro convict for a reasonable form of the honor system.

The character of the warden or prison superintendent who makes the selection of the men to be trusted and of the sergeant or deputy warden who is placed in charge of the camp has, of all factors, the most influence upon the success or failure of the honor system. It may almost be said that unless these officials are possessed of the ability to win the respect of the men and cultivate sentiments of loyalty and pride the system is foredoomed to failure.

GRADED SYSTEM OF DISCIPLINE.

From the preceding discussion it must be evident that the honor system of discipline can be applied to only a part of the entire population of any penitentiary or convict force. The reports of the proportions of men trusted in a number of States under the honor system and guard system, respectively, seem to indicate that under average conditions about 25 per cent of any force responds favorably to a reasonable measure of trust. The remainder must be guarded more or less strictly to prevent their escape. Success of a certain kind can be obtained by treating all convicts alike and subjecting all to the rigid discipline necessary for the government of the worst, but such a plan imposes unnecessarily severe restraint upon the better class and ignores the very considerable disciplinary value of a policy of treating the convict according to his deserts. The tendency of modern penology toward an increasing recognition of the shades of character among convicts and toward the substitution of rewards for penalties as far as possible can best be furthered by the adoption of a graded system of discipline in which both the guard system and the honor system have a place. The method of classification must necessarily be determined with respect to particular local conditions, and the following suggested system is presented as an example to indicate the proper bases of classification rather than as a recommendation for general adoption.

Class I.—This class should be quartered at the State penitentiary or the county workhouse or concentration camp. All recruits should be received into this class to remain a sufficient length of time to permit a determination of their character to be made. While they remain, they should be employed in the prison shops or at such indoor industries as may be provided where there is no elaborate prison establishment. As soon as they are classified they should be distributed among the other grades, and only those who are apparently best fitted for shop or indoor work should remain permanently in this class.

Class II.—To this class should be assigned all convicts who are evidently best fitted for hard outdoor work, but who are of such desperate and untrustworthy character as to require constant guarding, and whom it would be impossible to employ outside of an inclosure without shackling and clothing in striped uniforms. This class may very properly be employed within an inclosed stone quarry, a brick plant, or on a large farm, where the convicts can be entirely withdrawn from all contact with the public. They should be clothed in such distinctive clothing as stripes, which will attract immediate attention in case of escape owing to the fact that under this system convicts regularly employed in public will not be so clothed.

Class III.—This class should include convicts of a less dangerous nature than those assigned to Class II, and of such kind as to permit of their employment on the public roads without shackles or striped clothing and under a relatively light guard. They should be employed on works of heavy grading or in exposed quarries or at other work which is well adapted to the employment of gangs of not less than 10 men each. Convicts of this class may be clad in blue uniforms.

Class IV.—To this class should be assigned all convicts well fitted for outdoor work who can be trusted to work under the honor system. Clad in suitable uniforms they may be employed to advantage on all classes of road work. As an incentive to labor and good conduct, a small daily compensation should be provided for convicts of this class, and such compensation could be paid readily from the amount saved by the elimination of guards.

Class V.—This class should consist of convicts paroled from Class IV, who should be given an opportunity to serve their paroles as patrolmen on the maintenance of State or county roads. They should wear no regular uniform and should receive the full compensation of free laborers, but, during the period of their parole, they should be required to report monthly to a designated officer with regard to their satisfactory observance of the conditions of parole.

Provision for promotion or demotion of all convicts through the various grades, as the reward of merit or the punishment of misbehavior, will go a long way toward the mitigation of the cruelty of punishments, as the severest forms will be approached only by gradual descent, except in cases of violent assault, mutinies, and riots.

CAMP LOCATION.

As a rule, it was found that the officers in charge of the camps investigated were possessed of a general knowledge of the cardinal principles of camp location, and had applied their knowledge fairly effectively in the selection of their sites.

Accessibility to the road work was in general their first consideration, and usually their policy was to select the site near the center of the section of road to be improved. The average distance which it was considered practicable to cover from one location was 3 miles.

For more exact determination of the site the proximity of a supply of good water was considered as the controlling factor, though in the majority of cases it had not been thought necessary to make any special investigation of the character of the water they were using. Whenever practicable, the site was selected near naturally flowing sources of water, such as springs, mountain streams, and lakes, or when opportunity offered use was made of city water supplies and the wells of farms or residences close at hand. The digging of wells was avoided, where possible, on account of the expense involved, but when the impracticability of other sources made that expedient necessary there was an evident tendency to make a shallow well suffice.

The camp sites were usually high enough to secure dry soil and fair natural drainage, and several of the camps inspected in the Western States were splendidly located on the high banks of rivers or on knolls protected from the wind by trees. Other camps, both in the East and West, were established near the foot of hills and were exposed to flooding in rainy weather. It was not always possible to avoid locations of this character, and when the camps were allowed to remain only during the dry summer months little difficulty was experienced. As a rule, the camps in the Eastern States were abandoned during the severe winter months, while those in the South and far West were maintained throughout the year. Locations for winter quarters generally were chosen with considerable care, and everything that reasonably could be expected was done for the health and comfort of the men. In one of the Western States it has been the custom for several years past to move a camp of about 50 men more than 200 miles from its base and over 100 miles from a railroad in order to reach a climate sufficiently mild for the men to be employed during the winter months.

A few camps, most of them in the Eastern States, were laid out on rather marshy ground in the vicinity of pools of stagnant water. However, these were only temporary, and the officers in charge, while quite aware of the undesirability of the locations, stated that they were unable to find any land in the vicinity of the work which afforded better sites.

In one camp a bunk house was built under a very large tree with foliage so dense that the sun never could penetrate it. The structure was provided with board sides and a canvas roof, and the only opening was a single door at one end. As a result, its interior was dark and musty even in dry, midsummer weather.

CONSIDERATIONS WHICH SHOULD GOVERN THE SELECTION OF A CAMP SITE.

By selecting the site at the intersection of two or more roads which are to be improved, the mileage which may be constructed from one location may be increased proportionately.

The 3-mile limit mentioned above is fixed by consideration of the time required to transport the men from the camp to the work and back, and it depends therefore to a large extent upon the means of transportation employed. It is approximately correct when the men walk to work or are transported on the work wagons drawn by slow-moving mule teams, but if motor trucks are used, as is done in some instances, this distance may be increased to fully 7 or 8 miles with no sacrifice of economy, provided the general condition of the road surfaces permits the use of the trucks.

By judicious arrangement of the work and the exercise of a certain amount of foresight, it may be possible often to select a location for a camp which can be occupied for a period of five years or more if motor trucks are used, and from which all the roads lying within a radius of 7 or 8 miles may be worked. Furthermore, by a wise distribution of such camps over the county it may be possible to build them as permanent camps to serve their sections whenever there is work to be done in them, and so avoid entirely the necessity of moving or rebuilding camp structures. As stated, the success of such a system will depend upon the suitability of the roads, grades, and natural conditions for truck transportation; it will also depend upon the extent to which the truck can be employed for camp purposes and for road work when not used for transporting men. The system is being employed in a number of localities with apparently satisfactory results.

The general location of the site being thus determined with regard for its proximity to present and future work, other important factors serve to fix its position definitely. Most important of these factors is the availability of an adequate supply of good water, to secure which some sacrifice in distance from the work is justified.

Of the various sources from which water is obtained springs are most highly valued by a majority of people, because of their generally high degree of purity and the coolness, cleanness, and pleasing taste of the water. Springs are most frequently found under the slopes of hills, and except in rare cases it is impracticable to establish a camp directly at the site of a spring. It is therefore generally necessary to carry or pipe the water to the camp from a considerable distance, but this distance may be a distinct advantage owing to the fact that the danger of pollution by surface or subsurface washings from the camp is materially lessened.

Camps located in thinly populated mountainous sections frequently may be so placed as to receive their water by gravity from a mountain stream. While this is a very cheap and satisfactory form of supply it necessarily must be limited to those camps which are near an uninhabited watershed. For this reason it is imperative, before choosing a site depending upon such a supply, that a careful sanitary survey of the stream and its watershed be made, to avoid dangerous pollution by possible camping parties, even though no permanent dwellings may be found.

The selection of camp sites in sections where the underlying rock is limestone is a problem of especial difficulty, as explained under the topic of camp sanitation.

In cases where it is impossible to secure a site sufficiently near to a naturally flowing source of water it will be necessary to dig a well, in which case the aim should be so to select the site as to reduce to a minimum the cost of reaching water.

Whenever possible, the camp should be located on elevated and well-drained ground, as far as practicable from marshes, swamps, and pools of stagnant water, and in such direction from them that the prevailing wind in summer is from the camp to the swamp rather than in the opposite direction. The top of a low ridge, the summit of a knoll with gently sloping sides, or the high bank of a river is very desirable.

It is important that the location shall be such that the drainage from the camp shall not pollute the grounds and water supplies of dwellings or settlements in the vicinity; and it is equally important that the camp site be removed as far as possible from stables, pigpens, and other fly-breeding places not under the control of the camp authorities.

For camps designed for occupancy in winter weather a slope to the southward, with trees to break the force of the wind, is the most suitable location, but for hot-weather sites it is advisable to select high ground shaded by trees.

A side-hill site or one at the foot of a hill may be improved greatly by digging an intercepting ditch on the uphill side of the site to receive the surface water from the higher ground and carry it around the site. A similar expedient usually is adopted for the protection of tents. In this case, instead of a single ditch a number of small ditches are dug, one immediately around each tent.

The grouping of trees should not be so close nor their foliage so dense as to exclude the rays of the sun completely, for under these conditions the ground may remain moist and the buildings may become damp and unhealthful. Underbrush should be cleared away thoroughly because, in the presence of moisture, it affords breeding places for mosquitoes and also gives them protection in their flights. Closely cut grass on the camp grounds offers many advantages. It prevents the washing of the soil by rains, does not reflect the heat and glare of the sun, and aids in the prevention of mud and dust.

The most suitable soils for camping purposes are gravel and sand, as rainwater sinks into them quickly and the surface dries rapidly. Loams, so-called top soils, and sandy clays, while not so good as sand or gravel, are usually satisfactory. Clay is least desirable for the reason that it absorbs and holds a great deal of moisture which is given up but slowly by evaporation, and is especially disagreeable after a rain.

The site should be selected with a view to the disposal of the sewage, animal, and kitchen wastes of the camp; and a good site will afford a suitable location for the burial of this refuse or for a cesspool or other arrangement not less than 100 yards from the prospective location of the buildings, and in such position as to avoid the pollution of the water supplies of men and animals.

All of the sanitary conditions of a prospective site proving satisfactory, it should be examined with respect to its suitability for the accommodation of the necessary buildings, roads, and walks. It should afford a level or slightly sloping area of sufficient size to permit the convenient grouping of all buildings or structures without crowding. It is important from the standpoints of economy and cleanliness that grading for the reception of buildings be avoided. The sod should be preserved intact, particularly on a clay soil, to prevent the formation of mud and dust. Large or important structures should be separated by a distance of at least 30 feet to minimize the risk of spreading fire. Furthermore, the conformation of the site should permit the arrangement of the sleeping quarters, kitchen, and mess buildings of convicts and officers so as to admit as much sunlight as possible. To accomplish this it is necessary that these buildings be placed with their longer sides facing east and west.

The camp should be located near the road under construction or on a highway affording connections with the entire territory served by the camp and with the nearest town or city. It is desirable that the camp structures be elevated somewhat above the road and back from it far enough to avoid the dust; but the ground contours should be such as to permit economical construction of driveways and approaches.

When convenient, it is desirable that the site shall provide a fairly level open space where the convicts may be allowed to exercise under the supervision of their guards or officers and where, if possible, a baseball diamond may be laid out.

A limited area to serve as truck garden where fresh vegetables may be raised by the men is another desirable feature. In many camps it is found that the convicts enjoy the light work involved in the cultivation of the garden as a recreation after the day's work on the road.

The purely aesthetic considerations should not be overlooked entirely, as seems to have been done, unfortunately, in many of the camps inspected. On the contrary, the grounds surrounding the camp should be made as attractive as the conditions will permit. By saving large and graceful shade trees when the site is cleared, by sowing grass seed, by laying out and constructing walks of cinders or gravel, and by planting a few flowers as walk borders or in beds it is usually possible to make even the most forbidding site reasonably attractive in a short time and with little expense.

In selecting the site, thickly settled rural communities should be avoided if practicable, and the camp should be located as far as possible from a large city in order to minimize the chance of escape which the proximity of the city promotes; and, finally, after a site has been selected tentatively, it is proper to make inquiries in the neighborhood to ascertain the sentiment of residents regarding the presence of the camp among them. Neighboring property owners often have pronounced objections to settlement of convicts nearby, and whenever possible this sentiment should be respected.

Plate I shows a contour map of a desirable camp location with a good disposition of structures.

WATER SUPPLIES.

QUALITY.

Water obtained from any source may be sufficiently pure for use, but before deciding to use any given source the purity of its water should be determined by means of a bacteriological examination, and a thorough survey of the immediate and remote surroundings should be made to ascertain that there are no probable sources of future contamination which may be beyond the power of the camp officials to correct. Chief of such sources of contamination are privies, stables, barnyards, hog pens, pastures, and manured fields; and water supplies which can not be protected from the surface washings or direct ground leachings from these sources should not be used.

SPRINGS.

Twelve of the camps investigated obtained their water from springs. As a rule, springs form excellent sources of water supply, since they usually come from distant sources and are filtered through sand, gravel, and soil before reaching the surface; but occasionally they may originate not far away, and in such cases the water is more likely to be poorly filtered and easily polluted. Springs of the former class usually may be distinguished by the fact that they show a steady flow in both wet and dry weather and are not much influenced by the different seasons, while springs of local origin tend to disappear in dry weather and come up rapidly again immediately after a rain.

Though springs usually are of a high degree of purity in the absence of human settlements, when one of them is adopted as a water supply for a convict camp it may become subject to pollution from the camp itself, and unless its purity be safeguarded properly it may shortly become unfit for use. This pollution may occur by the seepage of the liquid contents of a privy, cesspool, sink, stable or garbage pit through the soil into the water vein, or by surface washings, from these and other sources, into the spring pool.

Contamination by seepage can be prevented only by locating the camp buildings, stock corrals, and other sources of pollution at a sufficient distance from the spring to make sure that any liquids which reach the ground water previously shall have become purified by filtration through the soil. In general, none of the structures or waste deposits should be located within a hundred yards of the spring and, if possible, they should be located on another slope.

For protection from surface pollution, the spring should be inclosed in a brick masonry or concrete box provided with a pipe inserted in the side for the overflow of the water; and as a further protection it is advisable to dig a ditch on the slope above the spring, so as to lead the surface water around the spring and into the overflow, as shown in Plate II. On no account should buckets or vessels be dipped into the spring for filling, but all water should be taken from the overflow-pipe. If the spring water be used for the cooling of food, a separate box should be built especially for that purpose; and water for other purposes, such as the soaking of tubs and buckets, may be obtained from the overflow a safe distance below.

Spring water supplies in limestone regions are subject to pollution carried from distant sources through the fissures and crevices in the rock, as stated under the topic of camp sanitation; and, as it is usually impracticable to find and correct the source, springs in such formations always should be regarded with suspicion.

WELLS.

Wells are of two general classes, shallow and deep. As a rule shallow wells are dug from 3 to 6 feet in diameter to a depth of from 20 to 50 feet, while deep wells are bored or driven to depths of 100 feet and more, often well down into the underlying rock.

Both shallow and deep wells are subject to pollution from surface sources and by subsurface leachings from privies, cesspools, and other sources, as described in the foregoing treatment of springs. However, deep bored or driven wells are less liable to pollution than shallow dug or bored wells, as the former usually are incased in metal pipes and the surface water, to enter the well, must filter through the soil to the depth of the well, while in the case of shallow wells, even when tightly lined, the surface water has a comparatively short distance to filter before entering at the bottom of the well.

About one-fourth of the camps investigated were using well-water supplies, and in general the surroundings of the wells were very unsanitary. Usually the wells were shallow ones 3 to 4 feet in diameter and from 12 to 30 feet deep. The main camp structures were generally from 35 to 50 feet away, with a privy of the hole-in-the-ground type not more than 100 feet distant and frequently at a somewhat higher elevation than the well. Stables and hogpens were in close proximity and chickens and pigs were allowed to roam about the camp. Laundering usually was done within a hundred feet of the well and the laundry wastes were thrown almost invariably upon the surface of the ground, while faces and hands frequently were washed almost immediately at the well, the dirty water being wasted on the ground. Such conditions as these almost certainly must result in the contamination of the water supply. The soil surrounding the well may remove the polluting substances at first by filtration but it soon becomes overburdened with organic filth, and finally, unable to perform its purifying function, allows the contaminating water to enter the well practically unchanged.

Wells in limestone regions are subject to the same danger of pollution as springs in such sections, and always should be regarded as of doubtful purity. When it is necessary to use a well in a limestone country, frequent tests of the water should be made to ascertain that no contaminating matter is being introduced.

Local pollution may best be prevented (1) by placing privies, stables, and all other possible sources of pollution at a safe distance from the well—never less than 200 feet—and on a slope below the well; (2) by keeping the surface of the ground about the entire camp scrupulously clean and free from filth of all kinds; (3) by constructing the well itself in such manner as to prevent the entrance of polluting matter.

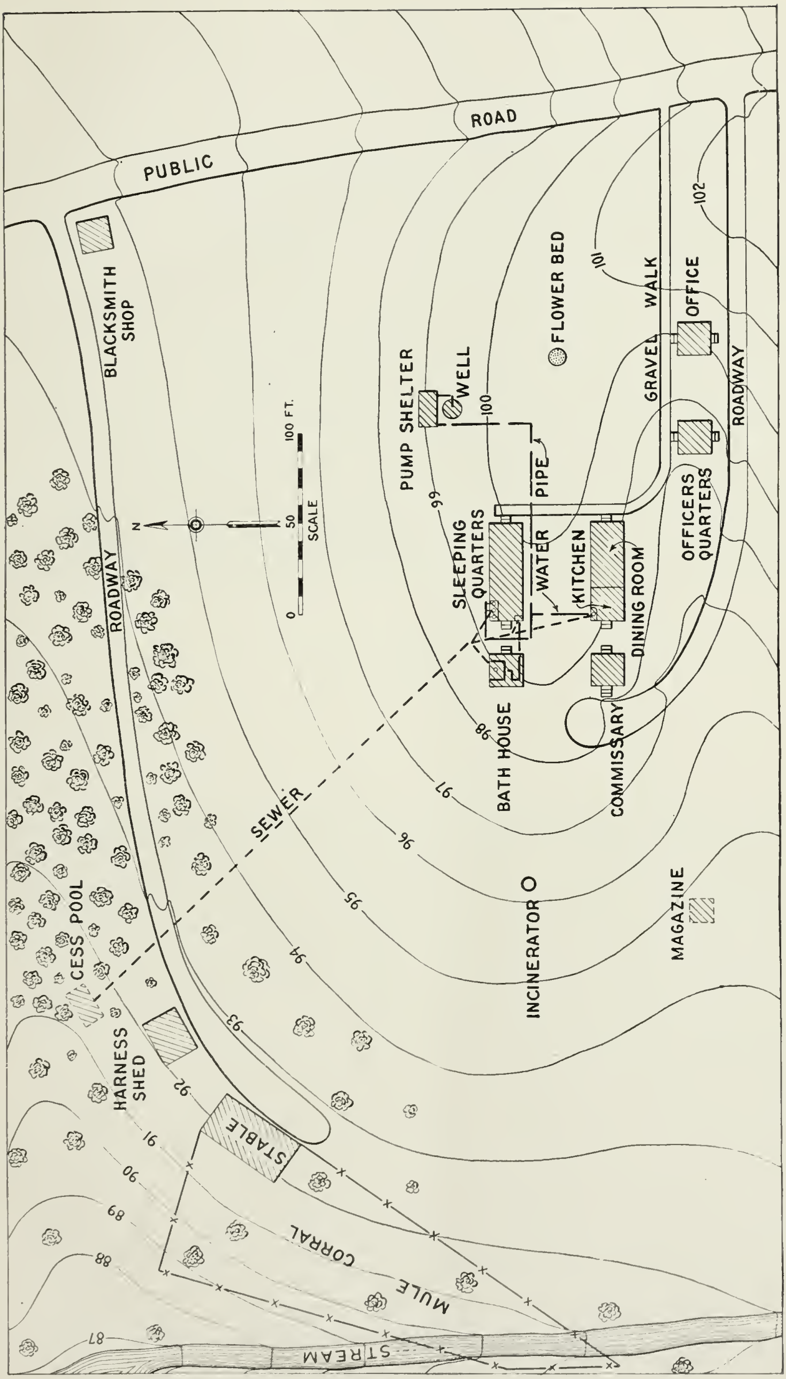
CONSTRUCTION OF WELLS.

A shallow dug well under ordinary conditions should be lined with some impervious material, such as concrete, brick or stone laid in cement and pointed on the inside, or terra cotta sewer pipe cemented at the joints; and this casing should be built as deep into the well as practicable. In temporary camps, those in charge usually feel that they can afford neither the time nor the material to construct casings of any of the materials mentioned above, and rather favor the use of wooden casings, used more for the purpose of preventing the sides from caving than for keeping out surface pollution. In such cases, all precautions as to the location of the well in relation to privies, stables, and other sources of pollution become more vital than ever. The space between the wooden casing and the earth should be very carefully filled with sand or earth tamped as the casing is put in. Sand is preferable because it is of value in aiding in the purification of any surface water which may percolate through it; clay is somewhat unsafe for the purpose, as some kinds of clay shrink and crack on drying, and if this occurs, polluted water may find its way through the cracks to the well. Wooden casings, however, should be used only in temporary camps, if at all. When used for long periods they decay and impart an unpleasant taste to the water, and in the end may be more expensive than one of the more durable kinds of casing.

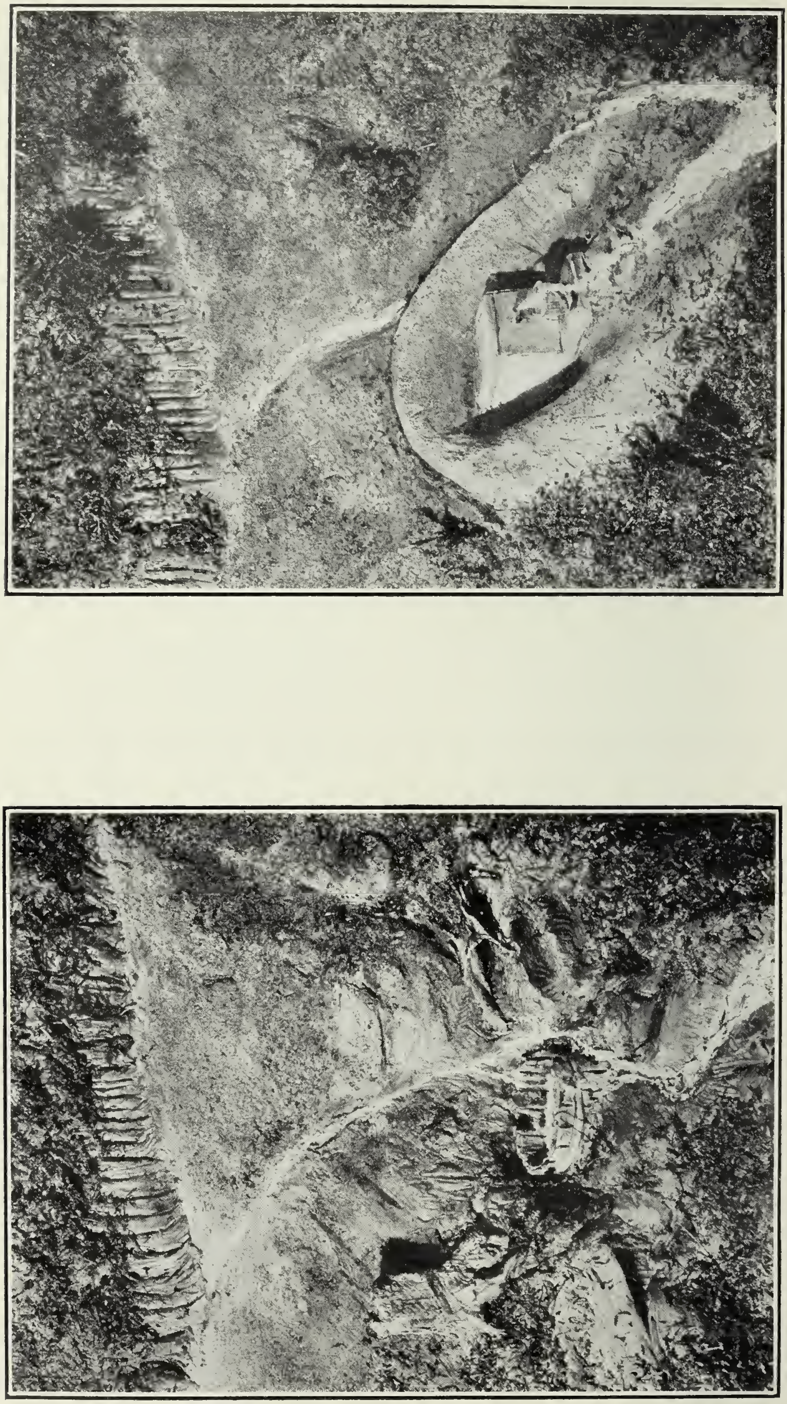
Driven wells are constructed by attaching a perforated point to the end of a pipe from 1¼ to 4 inches in diameter, and driving the pipe into the ground until water is reached. The water enters the pipe through the perforations in the point, which are small enough to keep out sand and gravel.

The upper end of the pipe usually is attached directly to a pump by which the water is raised. The vibration of the pipe, caused by the pump, often loosens the earth about the tubing so that a channel is formed through which surface water may enter the well; and the joints in the pipe also have been known to loosen so as to permit the entrance of surface water. To obviate the former trouble it is necessary to provide a heavy timber or concrete platform to which the frame of the pump may be fastened tightly. The pipe should be inspected occasionally with a view to the removal of all leaky and rusted sections. Waste water from the pump should be carried by a pipe or spout to a considerable distance from the well, and dirty water never should be used in priming.

When a distance of 100 feet or more is traversed before water is struck, the term "deep well" is commonly applied. If, after water



Desirable Camp Layout.



Types of Polluted and Well-Protected Springs.

has been reached, the well is continued through the hardpan or rock underlying it until another water-bearing level is reached, the well is called an artesian well.

Such wells are usually made by sinking an iron pipe to the required depth if the formation of the ground will permit, or by drilling in stiff soils and rocks. The water thus obtained usually has filtered through the ground for great distances and generally is free from pollution from human and animal sources. Such water may contain mineral salts in great abundance, being in some cases so disagreeable to the taste that it can not be used for drinking purposes. Questions are asked frequently concerning the possible injurious effects of mineral salts in water, and the methods of removing them. It is impossible to define their ill effects, if any, and, in general, it is not practicable to remove the salts.

To prevent the pollution of artesian wells from the surface it is necessary to observe the same precautions to prevent the leaking or rusting of the upper sections of pipe, as were outlined in the discussion of driven wells.

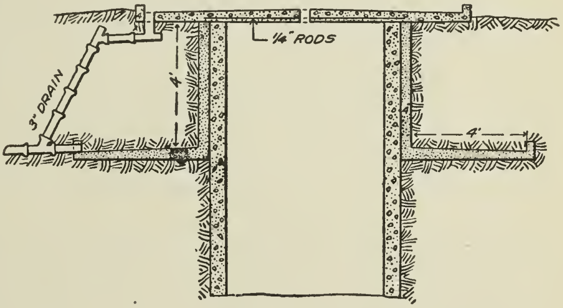


FIG. 1.—Well protection.

Both shallow and deep wells should have water-tight curbs in addition to impervious casings, for the drip from the pump often is the cause of serious pollution. The casing or lining should extend 6 or 8 inches above the ground surface, and a concrete curbing should be built over the top with a slope away from the pump opening in the center. This cover should extend about 4 feet beyond the edge of the well, with the outer edge raised sufficiently to force the waste water to run off through a tight drain tile, as shown in figure 1. In figure 1 there is also shown a method of protecting a well from direct contamination by unfiltered surface water.[1] To construct the cut-off shown, the earth should be excavated for 4 feet outside of the regular casing to a depth of 4 feet and an extra 4-inch coating of waterproof Portland cement mortar should be placed outside of the casing. The bottom of the excavation should be covered with from 4 to 6 inches of the mortar, and the outer edge of this layer should be raised so as to divert the seepage water to the tile drain. This arrangement will prevent from entering the well any water which has not been filtered through at least 4 feet of earth. A method of making water-proof

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[1] Suggested by E. Bartow in University of Illinois State Water Survey Bull. 7 (1909), No. 2.

Portland cement mortar is described in Bulletin 230 of the Department of Agriculture, which may be procured at 10 cents per copy from the Superintendent of Documents, Government Printing Office, Washington, D. C.

For the purposes of wells for temporary camps, in which a wooden casing is used, a certain degree of protection may be obtained by extending the wooden casing above the ground level and banking around it a shield of earth, 18 inches deep at the casing and sloping away from it to the ground level about 6 feet away.

If the water is to be raised from the well by hand, a hand pump is better from a sanitary standpoint than the familiar rope and bucket, since the bucket coming in contact with dirty hands may carry pollution to the water in the well. The joint between the pump and well cover should be protected with a tin flashing to prevent water from running back into the well.

If it be necessary to use a bucket, a shelf should be built on the side of the windlass box, so that when not in use the bucket may rest on the shelf instead of on the well cover. A better method suggested by the United States Public Health Service consists of a closed windlass box provided with an automatic device for emptying the bucket through a spout. By this method the handling of the bucket is avoided entirely.

SURFACE WATER SUPPLIES.

Surface water supplies are more liable to pollution than either springs or wells. Streams, lakes, and ponds receive a large amount of contaminating matter washed from the section which they drain, and usually the sanitary conditions of the up-stream watershed are beyond the control of convict camp officers.

DOUBLE WATER SUPPLIES.

Though the practice of using surface supplies generally is to be condemned, it is sometimes impossible to supply more than the drinking and cooking demands of a camp from underground sources. In such cases it may be necessary to resort to a surface supply to obtain water for washing and other purposes. This condition existed at one of the camps visited, and river water was being used, without any hesitation, for general camp purposes, notwithstanding the fact that it was known to be dangerously polluted, and had caused an epidemic of typhoid fever. It is true that the water was heated when used for bathing and washing clothes, but there could be no assurance that the temperature was high enough to kill the germs, nor, apparently, was there any hesitancy in adding unheated water in sufficient quantities to reduce it to a comfortable temperature for bathing. Furthermore, even when, as in the camp referred to, a pure water is provided for drinking purposes, it is a well-known fact that many persons are absolutely thoughtless in regard to the water which they drink, and an inferior water, if a little more convenient, will be used readily. Though no instances of this kind were reported at this particular camp, examples were not lacking in other places. At one camp a "trusty" convict working on the road drank water from a railroad culvert in order to save himself the trouble of going to the regular supply. It is significant that he was the only man at the camp who contracted typhoid fever. At another camp where the men were working under the honor system and were not under constant observation, several drank water from a river close at hand, although the camp supply was not far distant. Four contracted typhoid fever. The prisoners then were cautioned not to drink any water except that furnished for their use, and no more illness occurred. From the foregoing examples it is clear that danger may exist wherever a surface supply is at hand. To sanction the use of such a supply for any purpose whatever serves to increase the danger.

Whenever the use of such a supply is absolutely necessary, water used for all purposes should be purified, and the danger of using the unpurified water should be thoroughly drilled into the minds of the convicts. Harmful organisms are killed by boiling, but it is not certain that all the water used in the preparation of food will reach the boiling point, and much of the water used in washing dishes and clothing never boils. A method by which the danger may be overcome more certainly consists of the addition to the water of bleaching powder, otherwise known as "chloride of lime," "chlorinated lime," and "hypochlorite." In the quantities in which it is generally used for the purification of water for drinking purposes it is harmless in its effect upon the human body, and its taste is almost imperceptible. In cases where it is desirable to discourage the use of the water for drinking, the bleaching powder may be used in sufficient quantities to produce a disagreeable taste

The United States Public Health Service issues the following directions for the use of bleaching powder in the purification of water for drinking purposes:[1]

> Prepare a solution of bleaching powder (chloride of lime) by dissolving one teaspoonful of the fresh substance in one quart of water. This should be placed in a tightly stoppered bottle (preferably of dark glass) and kept from the light. To disinfect water, add one teaspoonful of this solution for each two gallons of water. Stir the water thoroughly and allow it to stand for fifteen minutes. At the end of that time the disinfectant will have killed the disease germs and the water may be drunk with a fair degree of safety.

As bleaching powder loses its strength very rapidly when exposed to the air, great care must be taken to keep it covered tightly in airtight containers.

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[1] Public Health Bulletin No. 70, U. S. Public Health Service.

QUANTITY.

The adequacy of the water supply of a convict camp is nearly as important as its purity, and before a given source is decided upon for use an investigation should be made to determine the quantity of water it will supply per day, and its sufficiency for the purposes of the camp.

The customary uses of water in convict camps are for drinking, cooking, kitchen washing, bathing, laundering, watering of stock, and fire protection. When it is to be used for all of these purposes the following table will give some idea as to the amount which should be available:

Approximate quantities of water required per day.

	Gallons.
For each inmate and officer	25 to 30
For each horse or mule	6 to 10
For each hog	2 to 3

Thus for a camp of 40 men and 5 officers, and maintaining 30 mules and 4 hogs, a minimum supply of 1,313 gallons per day will be consumed, based upon an estimate of 1,125 gallons for the officers and men, 180 gallons for the mules, and 8 gallons for the hogs. The water consumption will vary from day to day and from season to season, and will be greater in arid than in humid regions.

The amount of water supplied by the source should be somewhat in excess of the estimated consumption to provide for excessive drafts under unusual circumstances, and also to prevent the complete draining of the source each day, which is undesirable. Thus, for the camp assumed above, the supply should yield about 1,800 gallons per day, which represents a flow of 1¼ gallons per minute.

If the source be a well, the determination of the flow and the adequacy of the supply may be made as the well is dug by measuring the amount of water baled out in a given time. If it be a spring, a small bank of earth may be thrown up entirely around it, and in this way it can be forced to overflow through a pipe inserted in the bank. The flow then can be determined by noting the time required to fill a bucket or tub. When the source is a brook, there usually is little doubt of its adequacy for the purposes of camps of ordinary size. A stream only 12 inches wide and 2 inches deep and flowing at the rate of only 1 foot per minute will yield a supply of practically 1¼ gallons per minute, or enough for the camp of 40 men mentioned above.

STORAGE.

Assuming in the foregoing example that the flow of water from the source is exactly 1¼ gallons per minute, it will be observed that a full day of 24 hours will be required for the accumulation of the 1,800 gallons, necessary for the use of the camp. But this amount is used during only about half that time, and the length of time during which the water actually is drawn off is much less than that. It is therefore evident that some means must be provided of storing the water during the night for use during the day. If the source be a mountain brook, this may be done by constructing a dam which will impound the necessary amount of water. If it be a spring, the water may be stored by excavating a reservoir around it, or by constructing a concrete reservoir, while if a dug well be the source, the water may be impounded in any desired quantity in the well itself by carrying the well for the necessary distance below the water-bearing stratum or soil, and by making the diameter of the well sufficiently great. The dimensions of a driven well, on the other hand, are not sufficient to furnish such a reservoir and, therefore, unless the well be a so-called flowing well, in which case the water may be impounded in a reservoir above ground, it is necessary that the flow of the well be sufficient to supply the draft as required.

Distribution, Pumping, Etc.

The flow of water being sufficient for the needs of the camp, and sufficient storage or reservoir capacity having been provided, the next matter to receive consideration is the manner of distribution from the reservoir to the various parts of the camp.

The most primitive method is to have the water carried in pails or tubs by members of the camp force, and this method was in use in a number of camps visited. But it is very wasteful of time and labor, and unless the camp is expected to be of the most temporary character, more economical and convenient means should be provided.

In mountainous or hilly sections it happens frequently that the source, whether brook or spring, can be selected at a greater elevation than that of the camp, and under these conditions it is only necessary to lay a pipe line and the water will flow to all parts of the camp by gravity. This is simplest and cheapest and, when natural conditions permit, should be adopted.

However, when the natural conditions are not so favorable, and when it is desired to eliminate the carrying of water, one of three methods must be adopted, namely, the elevated tank, the hydropneumatic tank, or the pneumatic-pump methods.

Elevated-tank Method.

In the elevated-tank method water is forced into the tank from a lower level by means of a pump or ram and is discharged therefrom by gravity. "As there is considerable frictional resistance to the flow of water through the distribution pipes, the tank should be placed at least 10 feet higher than the highest discharge cock to insure a flow under pressure."[1]

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[1] From Bulletin No. 57, U. S. Department of Agriculture, "Water Supply, Plumbing, and Sewage Disposal for Country Homes."

Either wooden or metal tanks may be used. Wooden tanks may be obtained in almost any size, and are usually circular in section, and built of cedar or cypress staves, though juniper, fir, yellow pine, and white pine also are fairly satisfactory. As generally built the sides are battered not less than one-fourth nor more than one-half inch per foot of height; and the staves are held together by means of hoops which should be of wrought iron or mild steel and round in section rather than flat. Tanks are usually shipped "knockeddown," and should be set up and filled with water as soon as they are received. They are usually elevated on wooden towers, and, as set up, should rest on the tank bottom and not on the part of the stave that projects below it. All outdoor tanks should be covered to keep out birds and leaves or other débris. To prevent the covering being blown off it should be firmly fastened to the top of the tank by straps of iron. The ordinary life of wooden tanks is about 15 years.

Steel tanks cost from 40 to 100 per cent more than wooden tanks of the same capacities; but if kept well painted inside and out they will last an indefinite time. They are absolutely tight when once erected, whereas a wooden tank will shrink and leak if the water gets low. They are not liable to sudden failure, as sometimes happens with wooden tanks when the hoops burst. On the other hand, steel tanks are not well adapted to the use of convict camps because it requires skilled boilermakers to erect them. They are also more difficult than wooden tanks to protect against freezing.

This elevated-tank system was in use in six of the camps investigated. It may be employed satisfactorily in permanent camps, but it can not be used economically or conveniently in temporary camps on account of the time required to erect and raze the tank and tower when the camp is moved.

THE HYDROPNEUMATIC-TANK METHOD.

The hydropneumatic-tank method is more convenient for the use of temporary camps, as the elevation of the tank is avoided. The equipment necessary consists of a force pump operated by hand or power, an air-tight steel tank and valves, pressure gauges, and fittings. The operation of the system depends upon the fact that air is elastic and can be compressed while water can not be compressed. When water is pumped into the empty, air-tight tank, the air already in the tank is compressed into a smaller space in the upper part of the tank. This compression of the air causes it to exert a pressure which forces the water through the service pipe to the points of delivery. But, though the air can be compressed almost indefinitely, it always will occupy some space in the top of the tank, and hence the tank never can be filled to capacity with water. In practice it is customary to fill only from two-thirds to three-fourths of the volume of the tank with water. As the water is drawn off the pressure of the confined air diminishes rapidly and a point is soon reached where, though there still is some water left in the tank, the pressure of the air may not be sufficient to force it to the faucets. The following table shows the increase in the pressure of the air as water is pumped into a hydropneumatic tank.

TABLE 8.—*Increase in pressure as water is pumped into a hydropneumatic tank.*

Part of tank filled with water.	Pressure caused by compression of trapped air only.	Initial pressure pumped into tank.
	Pounds per square inch.	*Pounds per square inch.*
Empty	0.0	10.0
One-fourth full of water	4.9	18.2
One-third full of water	7.4	22.4
One-half full of water	14.7	34.7
Two-thirds full of water	29.4	59.4
Three-fourths full of water	44.1	84.1

A pressure of 6 or 7 pounds per square inch is necessary to overcome the friction in the piping and force the water to the height of faucets under average conditions, and it will therefore appear by reference to the above table that the volume of water which can be delivered at one charging of the tank, when only the air trapped in the tank furnishes the pressure, is not greater than one-half the volume of the tank. If, before the water is forced into the tank, a pressure of 10 pounds of air be pumped into it, all the water the tank will hold, which is not more than three-fourths of its volume, can be forced out. In practice, it is always necessary to pump a certain amount of air into the tank at intervals to overcome the loss caused by the gradual absorption and removal of the air by the water.

The following table gives the pressures in the tank theoretically necessary to force the water to certain elevations above the tank:

TABLE 9.—*Pressures theoretically necessary to force water to given heights.*

Height.	Pressure in tank.	Height.	Pressure in tank.	Height.	Pressure in tank.
Feet.	*Pounds per square inch.*	*Feet.*	*Pounds per square inch.*	*Feet.*	*Pounds per square inch.*
1	0.43	35	15.16	110	47.63
2	.87	40	17.32	120	51.96
3	1.30	45	19.49	130	56.30
4	1.73	50	21.65	140	60.62
5	2.17	55	23.82	150	64.95
6	2.60	60	25.98	160	69.28
7	3.03	65	28.15	170	73.61
8	3.46	70	30.31	180	77.94
9	3.90	75	32.48	190	82.27
10	4.33	80	34.64	200	86.60
15	6.50	85	36.80	210	90.93
20	8.66	90	38.97	220	95.26
25	10.83	95	41.14	230	99.60
30	13.00	100	43.30	240	103.92

In practice, the pressures given in the table will not force the water to the heights indicated because of the pipe friction. The amount of this friction depends upon the size and length of pipe, and the velocity at which the water is forced through it. The values given in the following table represent the frictional loss in feet of lift per 100 feet of pipe in pipes from three-fourths of an inch to 2 inches in diameter, discharging from 5 to 40 gallons per minute:

TABLE 10.—*Frictional loss in feet for 100 feet of clean iron pipes.*[1]

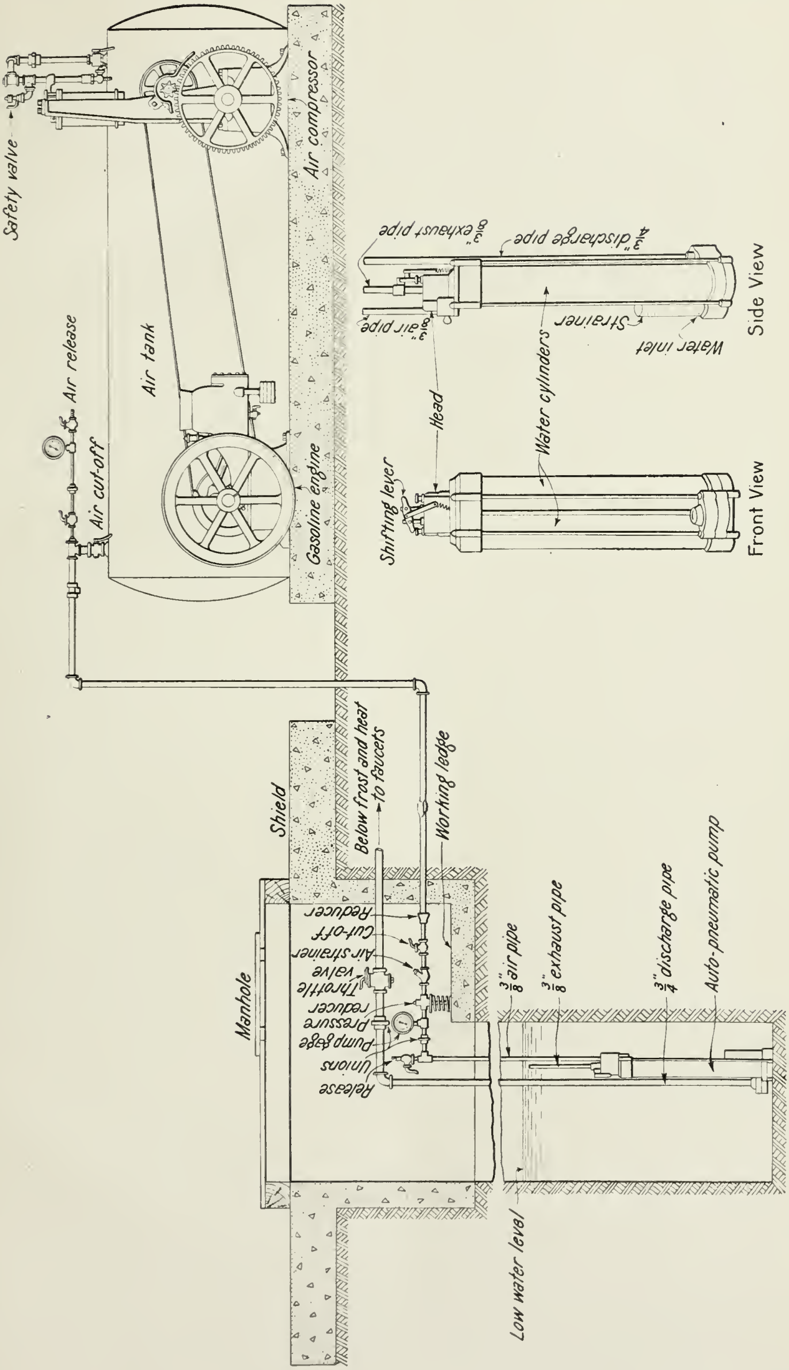
Gallons per minute.	¾-inch.	1 inch.	1¼ inches.	1½ inches.	2 inches.
5	7.6	1.9	0.7	0.3	0.1
10	29.9	7.3	2.4	1.1	.3
15	66.0	16.1	5.5	2.2	.6
20	115.9	28.3	9.4	3.8	1.0
25	181.4	43.7	14.7	6.0	1.5
30	....	63.3	21.0	8.6	2.1
35	....	85.1	28.5	11.6	2.8
40	....	110.4	37.0	15.0	3.7

[1] From Ellis and Howland's experiments.

The use of the foregoing tables is best explained by means of an example, as follows:

Example: It is desired to find the air pressure which will be necessary in a hydropneumatic tank to force water to two faucets, each 20 feet higher than the tank, at the rate of 5 gallons per minute to each faucet, the water for both being conducted for 150 feet through a 1½-inch main and then through two branch pipes each 30 feet long.

Solution: (1) The theoretical height to which the water is to be forced is 20 feet. (2) From Table 10 the frictional loss in forcing the water through 100 feet of 1½-inch pipe at the rate of 10 gallons per minute is equivalent to an additional height of 1.1 feet, and for 150 feet it will be $1.5 \times 1.1 = 1.65$ feet. (3) Also from the same table the frictional losses in forcing the water further through the two ¾-inch pipes for distances of 30 feet at the rate of 5 gallons per minute in each are equivalent to $2 \times 0.3 \times 7.6 = 4.56$ feet. Adding (1), (2), and (3), the total equivalent height will be $20.00 + 1.65 + 4.56 = 26.21$ feet. The pressure necessary to force water to this height is found from Table 9 to be 11.5 pounds per square inch.



VIEWS OF PNEUMATIC-PUMP SYSTEM AND PNEUMATIC PUMP.

The following table gives commercial sizes of pneumatic tanks:[1]

TABLE 11.—*Commercial sizes of pneumatic tanks.*

Diameter.	Length.	Weight.	Volume.	Diameter.	Length.	Weight.	Volume.
Inches.	*Feet.*	*Pounds.*	*Gallons.*	*Inches.*	*Feet.*	*Pounds.*	*Gallons.*
24	6	445	140	42	10	1,650	720
24	8	560	195	42	12	1,900	865
24	10	675	245	42	14	2,200	1,000
30	6	560	220	42	16	2,400	1,150
30	8	700	295	48	10	2,066	1,000
30	10	870	365	48	12	2,320	1,130
30	12	900	440	48	14	2,610	1,300
36	6	750	315	48	16	2,900	1,500
36	8	900	420	48	18	3,600	1,700
36	10	1,050	525	48	20	3,950	1,880
36	12	1,200	630	48	24	4,650	2,260
42	8	1,450	575	60	20	5,900	2,940

As stated above, the water capacity of the tanks given in Table 11 will be not greater than three-fourths of the volume of the tank. Therefore, for the camp of 40 convicts, assumed above, for which a daily supply of 1,800 gallons is necessary, it is evident that a tank 48 inches in diameter and 14 feet long would be required and it would be necessary to pump up this tank twice a day, starting with an initial air pressure of at least 11 pounds.

Pneumatic tanks usually are constructed to withstand safely a pressure of 100 pounds per square inch.

THE PNEUMATIC-PUMP METHOD.

By the pneumatic-pump method the water is delivered direct from the source. As it is not stored in a tank, storage capacity of other form must be provided, either a special reservoir or a sufficiently large dug well. The necessary apparatus consists of a small gasoline engine, an air compressor, an air-tight steel pressure tank, and a pneumatic pump. The operation of the method is as follows: The gasoline engine supplies power to run the air compressor which pumps the air in the tank up to any desired pressure. From this reservoir air under pressure is supplied to the pneumatic pump which is immersed in the water at its source in the well, lake, or brook. The pump consists of two small metallic chambers; when a faucet is opened these fill with water automatically and discharge alternately, owing to the alternate application of the air pressure from the tank to the surface of the water in each, and a continuous supply of fresh water is thus forced through the pipes.

Plate III shows a front and side view of a pneumatic pump and the arrangement of a pneumatic-pump system.

Each pump requires an air-pressure reducer, shut-off and release cocks, and pressure gauge. The air-pressure reducer is necessary to reduce the high pressure carried in the tank to the uniform low pressure required to operate the pump. It is placed in the air pipe line between the air tank and the pneumatic pump, and can be adjusted to the proper pressure with an ordinary wrench. The working pressure required to operate the pump and raise water to the required height is recorded on the pump gauge placed on the air pipe line between the reducer and the pump. The pressure necessary may be determined by the use of Tables 9 and 10, as described under the hydropneumatic system.

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[1] Bulletin No. 57, U. S. Department of Agriculture.

The size of tank that should be installed is governed both by the quantity of water to be delivered with one charging and by the pressure necessary to overcome the friction in pipes and fittings and to deliver the water at the required elevation. The following table shows the number of gallons of water that can be drawn from faucets with the pump under working pressures varying from 25 to 55 pounds, and with total starting pressures in a 1,000-gallon air tank varying from 60 to 100 pounds.

Table 12.—*Pumping capacity of a 1,000-gallon air tank, in gallons of water, under varying internal pressures.*

Pressure maintained in pump by pressure reducer.	Initial pressure in pounds in 1,000-gallon air tank.				
	60	70	80	90	100
Pounds.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*
55	40	155	270	415	550
50	140	270	400	550	700
45	240	385	530	685	850
40	340	500	660	820	1,000
35	470	650	830	1,010	1,200
30	600	800	1,000	1,200	1,400
25	737	918	1,239	1,350	1,618

For air tanks of other than 1,000-gallon capacity the amount of water which can be delivered with one charging can be obtained approximately by dividing the figures in the table by 1,000 and multiplying the result by the capacity of the tank in gallons.

For the purpose of the assumed camp of 40 convicts, an air-tank 48 inches in diameter and 14 feet long (the same size as the hydropneumatic tank selected) will supply all the water necessary for a day's consumption with one charging. Its volume, by Table 11, is found to be 1,300 gallons and if it is charged to an initial pressure of 100 pounds per square inch, and the pressure reducer set at 25 pounds per square inch, Table 12 indicates that the volume of water which can be delivered at one charging will be $\frac{1618}{1000} \times 1300 = 2{,}103$ gallons.

When the same tank was used as a hydropneumatic tank, it was found that it would be necessary to charge it twice a day, which indicates an advantage in point of convenience in favor of the pneumatic pump method. Those who favor this method claim as an additional advantage the fact that the water is not stored in a closed tank or in contact with stale air. On the other hand, the equipment necessary is more expensive than that required for the operation of the hydropneumatic tank method, and the mechanism of the pneumatic pump is somewhat delicate and demands careful attention to keep it in good running order. In particular, the pump must be protected from the action of sand or grit in the water.

PUMPS.

There are two general types of pumps, namely, suction-lift pumps and force pumps. The former depend for their action on the creation of a partial vacuum in the pump cylinder, which permits the water in the pump to rise above the water in the well. The maximum practical suction lift is about 20 feet, though it varies somewhat with the elevation above sea level, the greater the elevation the smaller the suction lift. This means that the pump cylinder which raises the water by suction in lift pumps should never be more than 20 feet above the water level in the well or other source. In force pumps the water is raised mechanically and the height to which the water can be raised is not limited as in the case of the suction pumps. Pumps of this type are necessary for use in connection with elevated-tank or hydropneumatic systems, and, unless a special air pump or compressor be used, it is necessary that a combination air-and-water force pump be employed for the hydropneumatic systems, especially in pumping from deep wells.

Frequently the two types of pumps are combined, the water being raised partly by suction and partly by force. This is accomplished either by the use of two cylinders, one for each of the operations, or by a combined suction and force cylinder.

Pumps are manufactured suitable for operation with any kind of power—hand, gasoline, steam, or electric. The most suitable form of power for the use of convict camps is that of the gasoline engine. For the purposes of camps of ordinary size from 2½ to 3 horsepower is all that is required, and a gasoline engine of such rating will not only pump all the water necessary but will furnish sufficient power to run a clothes-washing machine or other small machinery which may be useful around the camp. The horsepower necessary for pumping purposes in any case may be estimated by the following method:

Divide the number of gallons which it is desired to pump per minute by 7.48 (the number of gallons in a cubic foot), to determine the number of cubic feet of water to be pumped per minute. Multiply the number of cubic feet by 62.5 (the weight in pounds of a cubic foot of water) to get the weight of the water to be pumped per minute. Multiply this weight by the total lift in feet. The total lift will be equal to the vertical distance from the surface of the water at the source to the level of the water in the elevated tank plus the frictional loss in the pipes between the source and the tank as determined from Table 10; or if a hydropneumatic tank is to be used the total lift will be found by adding the frictional loss to the sums of the vertical distance from the surface of the water at the source to the tank and of the height which is found by Table 9 to be equivalent to the maximum pressure desired in the tank. Divide the result of the last operation by 33,000 and the quotient will be the theoretical horsepower required. But, as a pumping outfit usually is only about 50 per cent efficient, the theoretical horsepower derived by the foregoing operation should be doubled to determine the horsepower actually necessary.

Example: It is desired to determine the horsepower necessary to force water from a well 50 feet deep into the hydropneumatic tank, 48 inches in diameter and 14 feet long, selected for use in the camp of 40 convicts considered in the foregoing examples. The water is to be pumped at the rate of 900 gallons per hour, and a 1-inch pipe is to be used in the well. As a minimum pressure of 11 pounds is needed, the tank when three-fourths full of water will be under an internal pressure of 88 pounds.

Solution: By Table 9, page 79, the maximum pressure of 88 pounds is equivalent to a head of 204 feet of water. The vertical distance from the surface of the water in the well to the surface of the water in the tank is 50 feet. By Table 10, on page 80, the frictional loss in 50 feet of 1-inch pipe with water pumped at the rate of 900 gallons per hour, or 15 gallons per minute, will be equivalent to a head of 8 feet. Therefore the total lift is equal to $204+50+8$, or 262 feet. The volume of water to be pumped per minute is 15 gallons, or 15 divided by $7.48=2$ cubic feet. The weight of this volume of water is 2×62.5, or 125 pounds. Multiplying this weight by the total lift determined above, and dividing the result by 33,000, the power theoretically necessary is found to be $\frac{269\times 125}{33,000}$, or 1 horsepower, and allowing for 50 per cent efficiency of the outfit the power actually necessary is 2 horsepower.

Detailed information as to pumping installations may be obtained from pump manufacturers. In applying for such information it is proper to advise the manufacturer fully regarding the following points:

(1) The source of the supply (whether well, cistern, lake, or spring); (2) if a well, the inside diameter and total depth; (3) the distance from the ground surface to the level of the water in the well; (4) the flow of the well; (5) the number of gallons to be pumped per hour; (6) the relative positions of the source and the point to which the water is to be forced; (7) the position in which the pump

is to be placed; (8) the preference as to elevated tank, hydropneumatic tank, or pneumatic-pump methods; (9) the kind of power to be used (hand, gasoline engine, or electric motor); (10) the number of people to be served; (11) the approximate number of faucets desired and an estimate of the amounts of water to be used for various purposes; (12) the number of head of live stock of all kinds.

HYDRAULIC RAMS.

When there is available in the immediate neighborhood of the camp a spring or other supply of pure water so situated that a considerable fall may be obtained within a reasonable distance, a hydraulic ram may be used for pumping to the storage tank. The ram is a simple though wasteful machine, which utilizes the momentum of a stream of water falling a small height to elevate a portion of the water to a greater height; and once started the operation is continuous until the valves become worn.

The proper size of ram to suit any special condition is a matter which should be taken up with manufacturers of rams. It will depend upon the following factors:

(1) The flow of water from the source of supply, determined by the time required to fill a vessel of known capacity; (2) the difference between the level of the supply and the lowest point within a reasonable distance suitable for the location of the ram; (3) the distance between the source of supply and the proposed location of the ram; (4) the difference in elevation between the ram location and the highest point to which water is to be delivered; (5) the length of pipe necessary to conduct the water to the point of delivery.

In purchasing a ram, information with regard to the foregoing factors should be sent to the manufacturer.

The efficiency of a ram is governed by the ratio of the fall of water from the spring to the ram to the height to which water is to be pumped. It is greatest when this ratio is from 1 to 2½ to 1 to 3, and the ram usually will not work well when the height to which the water is to be pumped is more than 25 times as great as the fall from the spring to the ram.

The relation between the four interdependent factors, fall at the ram, lift to the tank, the supply at the spring, and quantity of delivered water are expressed approximately by the following equation:

$$q=\frac{Q\times H}{h},$$

in which

Q=supply of spring in gallons per minute,
H=fall in feet from spring to ram,
h=height of storage tank above ram in feet,
q=quantity of water pumped in gallons per minute.

Values of q and h, derived by the solution of this equation, should be reduced by about one-third to allow for friction, and values of Q and H should be increased in the same proportion.

Example: As an example of the use of the foregoing equation, suppose it is desired to determine the requisite flow of a spring to supply the camp of 40 convicts, in which the daily consumption is 1,800 gallons, the proposed location of the ram being 14 feet below the spring and 200 feet below an elevated storage tank.

Solution: As the ram operates throughout the entire 24 hours of the day the quantity of water in gallons per minute to be pumped, (which is q) is equal to $\frac{1800}{24\times 60}=1.25$ gallons. The height of the storage tank above the ram (or h) is 200 feet, and the fall from the spring to the ram is 14 feet. Substituting these values for the symbols in the equation,

$$1.25=\frac{Q\times 14}{200}$$

or,

$$Q=\frac{1.25\times 200}{14}=17.86 \text{ gallons per minute.}$$

Increasing this value by one-third to allow for friction, it is found that under the conditions named a flow of 23.8 gallons per minute will be necessary at the spring to force 1¼ gallons per minute into the storage tank.

Table 13 gives commercial estimates of the quantities of water delivered in 24 hours under various conditions:

TABLE 13.—*Capacity of hydraulic rams.*

Power head in feet.	Pumping head in feet.																
	4	10	15	20	30	40	50	60	70	80	90	100	120	140	160	180	200
2	540	192	128	96	64	43	29	24	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	301	192	144	96	72	58	43	37	27	24	.....	.....	.....	.....	.....	.....
4	.....	432	256	192	128	96	77	64	55	43	38	29	24	.....	.....	.....	.....
5	.....	540	345	240	160	120	96	80	69	60	53	43	30	26	.....	.....	.....
6	.....	.....	432	302	192	144	115	96	82	72	64	57	43	31	27	24	.....
7	.....	.....	505	378	235	168	134	112	96	84	75	67	50	36	31	28	25
8	.....	.....	.....	432	270	192	154	128	110	96	86	77	64	55	43	38	29
9	.....	.....	.....	485	300	216	173	144	124	108	96	86	72	62	54	43	39
10	.....	.....	.....	540	360	252	192	160	137	120	107	96	80	68	60	53	43
12	.....	.....	.....	.....	430	301	230	192	165	144	128	115	96	82	72	64	57
14	.....	.....	.....	.....	505	353	270	224	192	168	150	135	112	96	84	75	67
16	.....	.....	.....	.....	.....	432	323	257	220	192	171	154	128	110	96	85	77
18	.....	.....	.....	.....	.....	486	390	303	247	216	192	173	144	124	108	96	86
20	.....	.....	.....	.....	.....	540	430	336	288	240	214	192	160	137	120	107	96
22	.....	.....	.....	.....	.....	.....	475	370	303	264	235	212	176	151	132	118	105
24	.....	.....	.....	.....	.....	.....	520	405	346	288	256	230	192	164	144	128	115
26	.....	.....	.....	.....	.....	.....	.....	470	375	328	278	250	208	178	156	139	125
28	.....	.....	.....	.....	.....	.....	.....	505	430	354	300	269	224	192	168	149	134
30	.....	.....	.....	.....	.....	.....	.....	540	465	405	336	288	240	206	180	160	144

To determine the number of gallons delivered per day under any given conditions of power head, pumping head, and quantity of water used by the ram, multiply the factor opposite the given power head and under the given pumping head by the given number of gallons used per minute by the ram; and, vice versa, to determine the number of gallons per minute necessary to pump a given supply in 24 hours, divide the factor in the table into the supply.

Thus, in the above example, the supply required every 24 hours is 1,800 gallons. The power head is 14 feet, and the pumping head is 200 feet. Opposite 14 and under 200 in the table is 67. Dividing 1,800 by 67 the requisite flow through the ram is found to be 26.9 gallons per minute, as compared with 23.8 gallons determined by the formula above. Both results are approximate, and more accurate figures can be obtained only by a careful consideration of the length of the delivery pipe and the pipe friction. However, for the purpose of a preliminary determination of the practicability of a ram installation either method will provide sufficiently close results.

When it is determined to use a hydraulic ram precise instructions for the proper installation, operation, and care of the particular ram to be used should be obtained from its manufacturer, and these instructions should be followed carefully.

PLUMBING.

All piping used in connection with the water supply should be of iron, not lead, and the system should be so arranged that the water is carried to the point of discharge in as nearly a straight line as possible.

The main pipe from the storage tank never should be less than 1 inch in diameter, and for camps of 40 men should be 1½ inches in diameter. For camps of the latter size the branch pipes to the kitchen sink, wash trough, and shower fixtures should be not less than ¾ inch in diameter.

All pipes should be laid on sufficient slant to drain them back into the tank or drainage system, and a drain pipe and cock should be provided at a low point in the system so that in extremely cold weather the system may be drained into the cesspool or the tank to prevent freezing. This necessitates a stop cock on the pressure-tank outlet to prevent draining the tank.

Pipes exposed to the outer air or located where there is any danger of freezing should be boxed in sawdust or some other nonconducting material.

Hot water for kitchen purposes can be heated most conveniently and cheaply on the kitchen range, but for lavatory and shower bath it usually will be necessary to provide a special hot-water heater and a hot-water storage tank or boiler. In purchasing the water heater it is important that it shall provide sufficient area of heating surface in contact with the water to raise the temperature of the required amount of water to a proper point in a given time. The area necessary will depend on the nature of the fuel. If wood is to be used, the surface area of the jacket, water back, or tubes should be about 50 per cent greater than if coal is to be burned. By "forcing the fire" it is possible to increase the rate of heating, but this practice results in the premature burning out of the heater. As an aid in calculating the necessary heating surface the following, based on the use of coal as fuel, may be used:

> The average size of water back having about 110 square inches, or about two-thirds square foot, of exposed surface, will heat to the ordinary temperature of domestic hot water, 180° F., about 21 gallons of water an hour. It will heat about 17 gallons of water to the boiling point with an ordinary fire. With a fire such as is used for roasting, washing, or baking, a water back of this same size will heat about 23 gallons of water to the boiling point, or 27 gallons to the temperature of 180° F. Wrought-iron pipe-heating coils will heat from 30 to 40 gallons of water under the same conditions.[1]

When wood fuel is used, the above performances should be reduced one-third. It must be borne in mind that the temperature required for bathing is only about 100° F., and therefore it is not necessary to heat the entire quantity of water which is to be used to 180° F. On the contrary, with the temperature of the cold water at 60° F., only one-third of the water necessary for bathing need be heated to 180° F. to give a temperature of 100° in the mixed water as it comes from the showers.

To act as a reservoir of hot water a tank of from 50 to 100 gallons capacity should be coupled to the heater. By heating the water capacity of such tank before the bathing of the force is begun it is possible to reduce the rate at which the heater will be required to heat water, and thus decrease its size.

Steel tanks are most satisfactory for camp use, and they should be galvanized inside and out, particularly inside. Ordinarily, they are tested to withstand a pressure of 150 pounds, and extra heavy ones 250 pounds per square inch. The latter should be used when the gauge pressure at the tank is more than 40 pounds per square inch.

NOTES ON FIXTURES AND APPLIANCES.

The most suitable form of shower-bath fixture is a nickel-plated spray head 3 inches in diameter which may be obtained at a cost of approximately 25 cents.

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[1] Cosgrove, J. J., *in* Kidder's "Architects' and Builders' Pocket Book."

For camps where a supply of running water is not available a simple shower device may be improvised by attaching a spray head of the type mentioned above, to a faucet or cock in the bottom of a 5 or 10 gallon can so arranged that it can be raised by means of a rope running through a pulley attached to the roof.

When running water is available it is proper to provide more than one shower fixture, and experience indicates that one fixture for from 7 to 10 convicts is a desirable proportion. The use of bath tubs is to be discouraged. The shower bath is more convenient and more sanitary.

Wash troughs for use in connection with running water should not be provided with stoppers, but should act only as collectors for the waste water, and the convicts should be required to wash their faces and hands under the running water from the faucets. Troughs may be made of wood lined with galvanized iron or of a heavier weight of iron alone. Unlined wooden troughs should not be used. One faucet should be supplied for every 10 men.

Kitchen sinks may be of galvanized or enameled iron. The space under them should be left open.

CAMP SANITATION.

DISPOSAL OF EXCRETA.

The Pail System.

Pails are used extensively throughout the country for the temporary reception of human excreta and when used properly are peculiarly well adapted to the needs of guarded convict camps. Galvanized metal pails with tightly fitting covers and having a capacity of about 3 gallons are commonly employed. About 1 pint of a solution of coal-tar disinfectant is placed in each pail.

In some of the camps, pails in the proportion of one to every five men were brought into the bunk houses immediately after the prisoners had been chained for the night, the chains being arranged so that the men could move for a distance of about 6 feet from their bunks. After the prisoners were ordered "down to sleep," any man who wished to use the pail was required to attract the attention of the guard by raising his hand.

It is evident that when the pails are allowed to remain for a long period inside the bunk houses, they become quite objectionable. Some of the camps had the pails removed and emptied at intervals during the night and at other camps they were brought in at 8 p. m., used, and immediately removed, cleaned, and placed outside the bunk houses. They were again brought in at midnight and again at the rising hour. This latter practice was the most satisfactory from every standpoint. Some conditions were found during the course of the investigation which could not be justified on any possible ground. An indefensible custom which seems almost universal at convict camps is to provide insanitary privies for the use of the guards and the five or six trusty convicts who work about the camp during the day. This practice nullifies the good effects of a well-managed pail system, as these insanitary privies are likely to make the entire camp insanitary. Such conditions could be corrected easily by providing covered pails inside the privies.

PROPER CONDUCT OF PAIL SYSTEM.

The coal-tar disinfectants of which mention has been made are in general use for this purpose and are very satisfactory. The United States Public Health Service recommends that 1 quart of the solution be used to 6 quarts of sewage. Chloride of lime is an excellent and cheap disinfectant and may be used instead of the coal-tar product. A solution of the proper strength may be made by dissolving 1 pound of the disinfectant in 8 gallons of water and should be used in the pails in the proportion of 1 teacupful of the solution to each deposit of excreta. The chloride of lime should be kept in tight containers as it loses strength rapidly when exposed to air. To prevent splashing, a thick piece of paper or several small pieces of wood or chips may be dropped into the pail just before it is used. The pails should be cleaned and washed daily, but under no circumstances should they be rinsed in the vicinity of the well or spring.

At all camps where pails are in use the excreta is disposed of finally by dumping into pits and covering with earth. These pits, in all cases, were a sufficient distance away from the camps, but it might be mentioned that the minimum distance should be 100 yards, and the pits should be so placed that they are on a lower level than the water supply of the camp. Chloride of lime should be sprinkled into the pits at intervals. As the natural agencies of purification are present to a greater degree in the upper layers of the soil, it is better that excreta should be given shallow burial rather than thrown into deep pits. The deeper the pit the greater the danger of polluting underground water supplies. Instead of the large pits now in use at a majority of the camps, shallow furrows or trenches should be dug. These should be from 6 to 12 inches deep, and the excreta should be scattered along in a layer of about 2 inches in thickness, and should be covered immediately with 6 to 12 inches of earth. The furrow should be marked with stakes, so that there may be no danger of digging in the same place twice. Furrows made with the ordinary plow are entirely satisfactory. In cold climates the trenches for winter should be about 2 feet deep, and a sufficient number should be dug before the ground freezes. They should be filled with earth as soon as the ground thaws out enough to permit it.

Privies and Pits.

A great majority of convict camps use privies and pits for the disposal of human excreta. At only 4 camps out of the 30 at which some form of pit privy was in use was there any attempt to manage the disposal of excreta along sanitary lines. At three of these camps sanitary fly-proof privies were in use, while at the fourth a trench 2 feet wide, 12 feet long, and 12 feet deep was provided with a latrine box and the contents burned out each day with kerosene oil and hay.

At the other camps, insanitary privies of varying degrees of filth were provided, while flies were present everywhere and had easy access to the accumulation of filth. At two camps where men were confined in cages toilet seats had been placed over holes in the flooring and pits dug 4 feet deep and 18 inches in diameter to receive the excreta. The cages were not screened, nor were the pits. Over this mass of sewage human beings lived and ate their meals. At other camps where the men were locked in cages a tub was placed on the ground under the cage to receive the excreta. The tubs frequently contained a little disinfectant, but at only one camp was any attempt made to protect the excreta from flies.

At several of the largest camps, pits about 6 feet long, 2 feet wide, and from 4 to 6 feet deep were provided for 50 men. A pole, supported on cross logs at the ends of the pit, was used as a seat, while burlap or canvas surrounded the pit to afford privacy. There was no overhead protection.

These pits are objectionable because they are freely accessible to flies, while the filth may be carried quite a distance on scraps of toilet paper and on the feet of the men. In order to make pits as unobjectionable and harmless as possible, it is the consensus of opinion among Army sanitarians that the pits should be boxed and converted into closed vaults, from which flies may be excluded. The pits should be as far as possible from the water supply of the camp, and so located that they will not be flooded in rainy weather. Drain ditches should be dug around them or on the side from which drainage water might be expected. Pits should be about 2 feet wide at the top and about 6 feet deep. When they are filled to within 18 inches of the surface they should be covered with earth and other pits dug.

A box (fig. 2) devised by Maj. William Lister (military surgeon, May, 1912) might be used to good advantage at convict camps. The box is 8 feet long, with four holes, and is provided with a grip at each end for convenience of handling. The top is 18 inches wide, with a slope of 1½ inches to the rear to drain rain and wash water. The circular holes are 11 inches in diameter. The lid is extended forward flush with the top edge, so as to keep the seat dry, and it has a block nailed on the upper side to prevent its opening to a right angle. A block (2 by 3 inches) is nailed at each end of the upper edge in front, so that when the box is turned over this edge may not be soiled or scratched. A piece of tin (8 by 10 inches) is fastened by its upper edge to the inside of the front wall, opposite each seat, and set at an angle which causes the urine projected against it to fall clear into the pit. The box is set on a frame, so as to make the contact with the ground closer. This renders the box more completely fly proof, and protects the edges of the pit from wear and tear. To hold the box on the frame, a strip of board 4 inches wide is nailed 1 inch inside the lower edge of the box, thus projecting 3 inches clear and snugly fitting inside the frame.

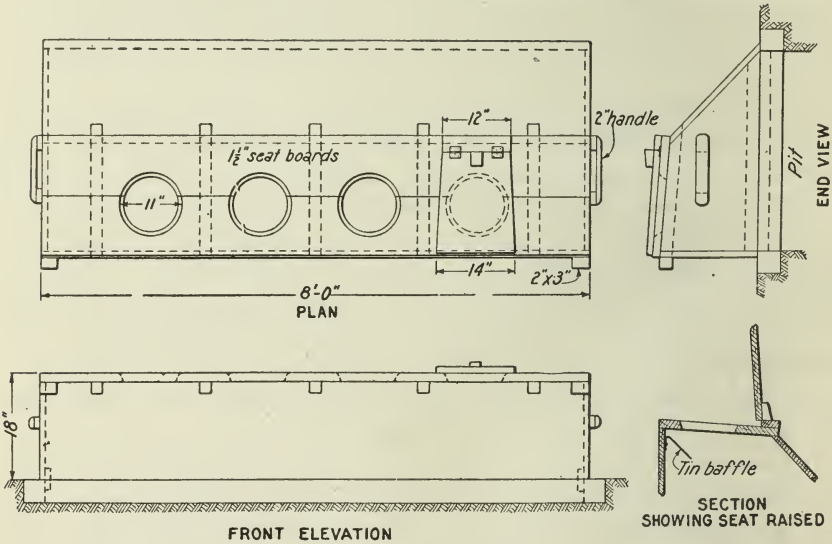

FIG. 2.—Lister latrine box.

Disinfection of a pit by fire has been practiced to a considerable extent in the United States Army and the results have been very satisfactory.

> At about 9 a. m., after a majority of the men have visited the pit, the box being lifted to one side, a layer of straw, grass, or hay (about 20 pounds for a pit 10 feet long) is evenly spread over the contents, sprinkled with a gallon of crude petroleum, and

set on fire. The hot blaze destroys all the germs lying near the surface of the excreta as well as on the sides of the pits, and completely removes all odors.[1]

Some authorities believe that still better results could be obtained by using oil alone in increased quantity (by an additional quart) as the residue from burned hay or stray fills the pit uselessly. The effect of the burning decreases in the afternoon, and odors, especially on warm days, may again become noticeable; then a liberal coating of lime is recommended, or of fine dry earth. Crude petroleum or diluted formalin sprinkled into the pit is useful at any time as a disinfectant and to repel insects.

At one camp in Mobile County, Ala., the boxed pit was in use, and was disinfected with fire each day in the manner described. The pit, which was sheltered from view by a thatching of pine branches, was in good condition and free from odors, and the camp authorities were enthusiastic over the satisfactory results obtained.

During the night, when it is impracticable to allow convicts to visit the pit, pails may be used in the quarters, as already described.

DISPOSAL OF EXCRETA IN LIMESTONE REGIONS.

In regions where there is limestone formation the danger of the pollution of camp or other water supplies by human excreta is greatly increased. Because of the fissures, channels, and crevices which abound in limestone, the excreta may find its way almost directly to water which is drawn from the well or spring, and this may occur even when the excreta has been disposed of at a long distance from the camp—a half mile or even much farther. The depth at which it is buried also may have little effect in such cases. The ordinary privies, cesspools, and pits are, therefore, very dangerous in limestone localities.

The burning or boiling of all excreta is the surest way of making it harmless, but this is a somewhat tedious and expensive process and frequently is almost impossible to accomplish in convict camps.

The following method, if carefully adhered to, will render the excreta practically harmless, and its use exactly as described is urged at all camps in limestone regions:

1. Use either the pail system, or a sanitary privy with water-tight receptacles.

2. Every time a deposit of urine or feces is made in a pail or privy can, throw in a cupful of chloride of lime solution and a small handful of slaked or unslaked lime. The solution should be made by dissolving one pound of chloride of lime in 8 gallons of water. It must be kept in tightly stoppered bottles so as not to lose its strength.

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[1] Havard, "Military Hygiene," p. 630.

The slaked or unslaked lime may be kept in an open box and is to be used as directed in conjunction with the chloride of lime solution. It is not sufficient by itself, but creates an alkaline medium in which the action of the chloride of lime is most effective. It can be purchased for about 75 cents a barrel.

3. Provide a watertight steel-coopered barrel with a stout cover. This may be mounted for convenience on wheels or on a hand truck. Dump all excreta from the cans and pails into this barrel every morning and allow it to stand until the following morning in order that the disinfectants may have time to reach and destroy the organisms. During the time that the mass is standing it need not be more than 100 feet from the camp. It will be neither offensive to the senses nor will it attract flies to any extent. It should, however, be kept covered. After 24 hours haul it away from the camp, 100 yards or more, pour it into a shallow trench similar to a plough furrow and cover with the excavated earth. The barrel then is ready to be returned to the camp and used over again in the same way.

DISPOSAL OF EXCRETA AT PLACE OF WORK.

With very few exceptions the roads being constructed by convict gangs led through sparsely inhabited regions with much vacant land on either side of the road. It was the common custom for the men to move a few feet from the side of the road and deposit their excreta on the surface of the ground. As the construction work progresses with fair rapidity, very few deposits of excreta are made in any one place, but, on the other hand, a certain amount is scattered over a considerable territory, and there is danger that some may reach streams or springs which furnish the water supplies for dwellings.

To prevent this it is a very simple matter to require each man to dig a hole in the ground from 6 to 12 inches deep and cover his excreta with the earth immediately. This method, which is already in use among certain groups of convicts, embodies excellent sanitary principles and is similar to that prescribed by Moses to the children of Israel (Deuteronomy XXIII, 12 and 13).

When prisoners are at work in more thickly populated districts it is the custom to provide for their use a small portable privy and to dig a shallow pit each time the privy is moved. This method is without objection provided the privy is kept a safe distance from wells and other water supplies, and each fresh deposit of excreta is covered immediately with earth.

VOIDING EXCRETA ON THE SURFACE OF THE GROUND.

At three of the camps inspected no toilet facilities whatever were provided. The reasons given by the officials were: (1) That the camp was moved so often (every two months); (2) that this method was as good as any other; and (3) that it was what the convicts were used to, and that the health of the men showed that the method was all right.

This method is neither safe nor cleanly, and it is because of carelessness of this sort that typhoid fever, dysentery, Asiatic cholera, hookworm, round-worm, pin-worm, and tapeworm diseases persist and are transmitted from person to person. Officials who are charged with the safe keeping and reformation of law breakers should, when the opportunity presents itself, endeavor to inculcate clean methods of living.

It should be perfectly apparent that the camp may be contaminated by excreta on the surface of the ground; that such excreta may be carried to the camp by the feet of men and animals, by flies, and by rain. Danger through contamination of the water supply and the food, or through direct infection, is ever present where such methods are permitted.

THE SANITARY PRIVY.

A sanitary privy should afford privacy and comfort to the user and have a water-tight receptacle to receive the excreta. This receptacle should be protected to prevent access of flies or animals to its contents and so arranged as to be cleaned easily.

In order that the sanitary privy may serve its purpose, the inmates of the camp should be rigidly prohibited from voiding their excreta at the outskirts of the camp rather than making use of the privy.

Privy seats and floors should be scrubbed with soap and water each day. Toilet paper, with fixtures to prevent its becoming scattered, should be provided. Rigid rules should be made and penalties imposed for their violation. A bucket of clean water, soap, and a couple of basins should be placed in a conspicuous position near the privy, and the waste, after washing the hands, should be emptied into a receptacle provided for the purpose. Excreta find no more direct passage into food, drink, and human mouths than by hands soiled by accident or by carelessness.

As already pointed out, guards and "trusties" usually are provided with insanitary privies, or they are permitted to pollute the surface of the ground. The following device, described by the United States Public Health Service[1] is a simple way in which to make conditions sanitary.

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[1] Public Health Bulletin No. 68, "Safe Disposal of Human Excreta at Unsewered Homes."

COVERED CAN.

This type [fig. 3] consists of a stout water-tight can fitted with a wooden top having a suitable hole in it to serve as the seat. The hole in the seat is covered by a hinged lid. The seat board is closely fitted to the top of the can and the lid fits closely over the hole. To provide ventilation, the lid may be a framed screen. This simple type of sanitary privy, which can be set up for about $1, if operated with care can be kept sanitary.[1] Where a sanitary privy house already exists it can be improved by filling the old pit with earth, removing the old seats, thoroughly cleaning the interior, laying a new floor and installing one or more of these box tanks.

Any water-tight receptacle of suitable size may be used in a sanitary privy. Experience has shown that wooden receptacles soon warp, become leaky, and are, therefore, unsafe, and in the long run expensive. Cylindrical cans made of strong galvanized iron generally are most suitable. A can about 15 inches in height and holding about a bushel is a convenient size. This type of can costs about 60 cents and is obtainable at most any store where hardware is sold. The painting of the inside of the receptacle with coal tar increases durability and makes cleaning easier.[1]

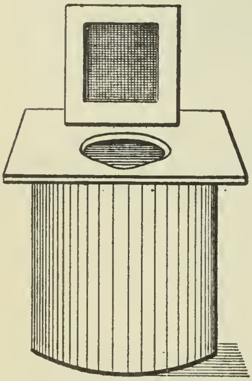

FIG. 3.—Covered can. The simplest type of sanitary receptacle privy. Used with a suitable drying powder, or disinfectant solution, it may be kept sanitary and practically odorless. The seat should be provided with cleats on the under surface to hold it in place on the can.

The cans should be inspected frequently to see if they leak.

SANITARY RECEPTACLE FOR USE WITH CONVICT CAGES.

A water-tight metal receptacle should be obtained at a hardware store. This should be of sufficient size to hold the excreta voided by the men from the time they enter the cage at night until they leave the camp for work the following morning, and in addition to this it must hold 1 gallon of a strong solution of coal-tar disinfectant for every bushel of capacity of the receptacle. A wooden box, fly-tight and substantially constructed, should be built to contain the receptacle (Fig. 4.). This box is to be fastened firmly to the flooring under the cage by means of angle irons and bolts, and should be placed so that the receptacle which it contains will be directly under the hole in the floor through which the excreta pass. The most accessible side of the box should be hinged in order that the receptacle may be removed each day for emptying and cleaning. The toilet seat inside the cage should be provided with a tightly fitting hinged lid, so arranged as to drop into place of its own weight when the seat is not in use. For purposes of ventilation and easy removal it is well to have a space of two or three inches between the top of the receptacle and the under surface of the flooring of the cage. A flue made of a few lengths of stovepipe and a couple of elbows extended from one side of the box to near the top of the cage will

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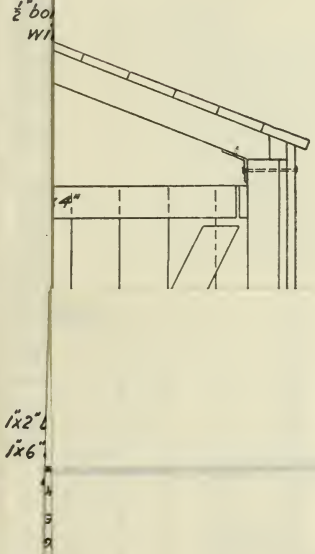
[1] Public Health Bulletin No. 68.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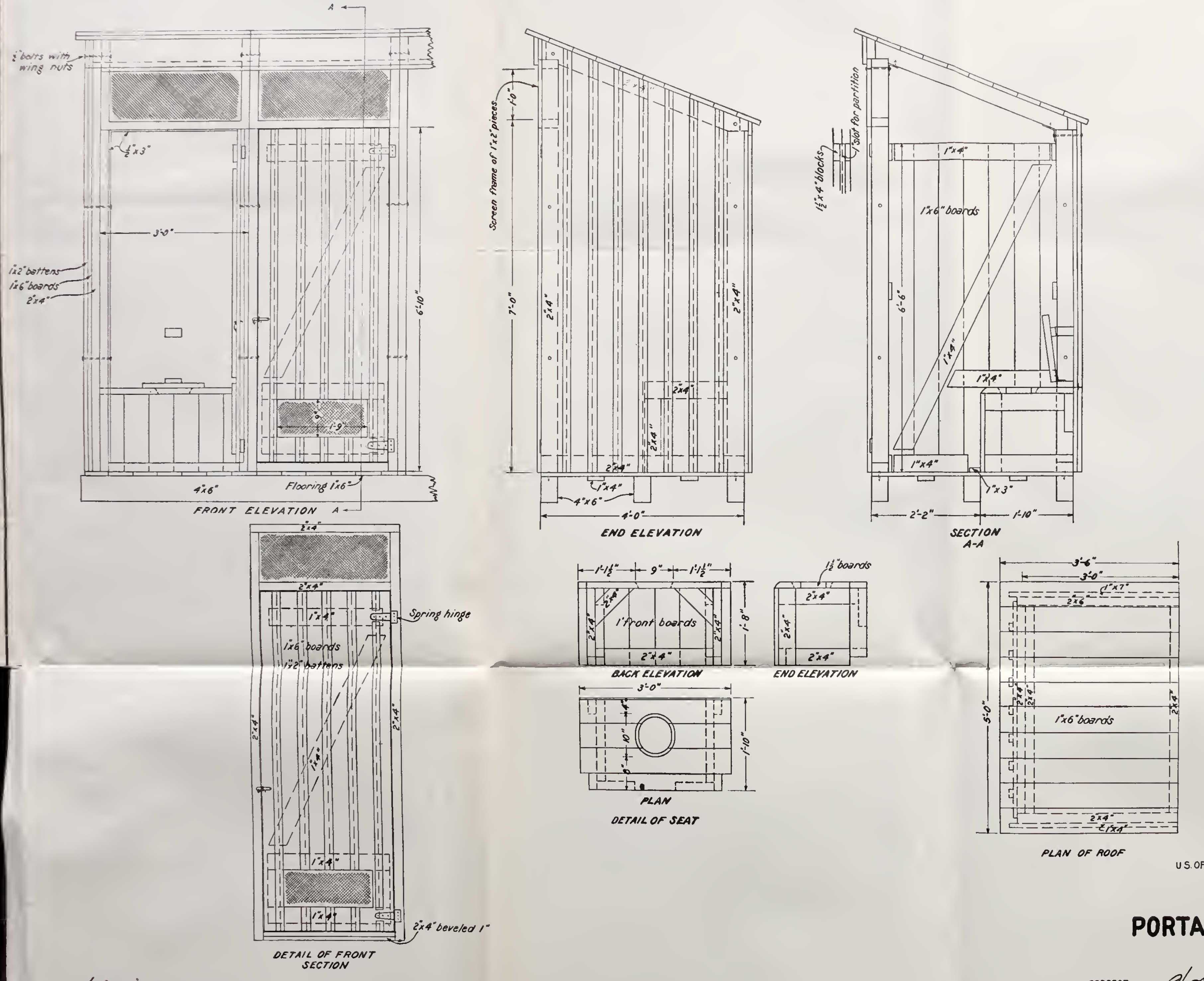

U.S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

DETAILS
PORTABLE FLYPROOF PRIVY

SCALE, 1" = 1'-0"

CORRECT H. S. Fairbank HIGHWAY ENGINEER

APPROVED J. E. Pennybacker CHIEF ROAD ECONOMICS

E-56

DESIGNED BY. H. S. Fairbank DATE 2-15-16
TRACED BY. G. C. Dunn DATE 2-18-16
CHECKED BY. H. S. Fairbank DATE 2-18-16

carry away bad odors. The opening of the flue in the box should be screened against flies.

PORTABLE PRIVY.

A design for a sanitary, flyproof, portable privy for use in connection with camp buildings, or in convict camps subject to more or less frequent moving, is shown in Plate IV. It is so arranged as to provide a separate and private compartment for each occupant, and may be constructed to accommodate as many occupants as desired, as each compartment forms a section of the entire building. At least one section should be provided for every 15 convicts. The door is provided with a hinged spring so that it will close automatically and the ventilating and other openings are all screened. The screened opening at the bottom of the door serves not only as a ventilator, but also, by affording a view of the legs of the occupant from the outside, as a means of checking the abuses which frequently arise in convict camps where it is possible for more than one person to occupy a privy compartment at the same time.

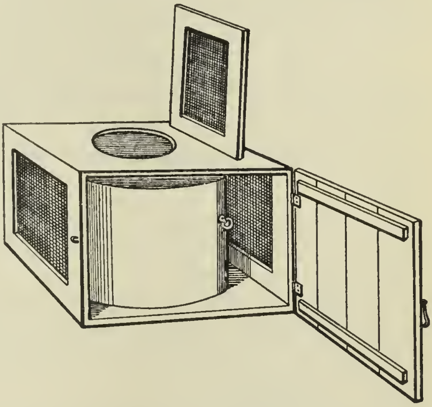

FIG. 4.—The boxed can. Flies are excluded by the fly-tight box. Such a device is safe, sanitary, and convenient, and may be placed in an existing privy or in any suitable outbuilding.

SEWERS AND SEWER PLUMBING.

Camps in which running water is supplied also must be provided with an adequate system of sewers and sewer plumbing to carry off the water and water-borne wastes of the kitchen, lavatories, shower baths, and water-closets.

The sewer or the main pipe leading from the camp to the point of disposal should be of salt-glazed, vitrified clay not less than 6 inches in diameter, with bell and spigot joints, and the joints should be filled with cement mortar. The pipe should be laid in as nearly a straight line as possible from the camp to the disposal point, and care should be observed to eliminate abrupt irregularities in the grade. In relatively temporary camps the pipe need be buried only about 1 foot under the ground, except under roadways, where it should be at least 18 inches under the surface. In permanent camps it will be well to lay the pipe from 2 to 4 feet below the surface of the ground. In no case should a sewer pipe be laid within 100 feet of a well.

The sewer plumbing carries the waste water from the water-using fixtures to a point about two feet outside of the building or buildings, where it joins the sewer tile.

The various pipes of the plumbing system are termed, according to the function they serve, house drains, soil pipes, waste pipes, and vent pipes, which terms are defined as follows:

House drain: That part of the main horizontal drain and its branches inside the walls of a building and extending to and connecting with the sewer tile.

Soil pipe: A vertical or nearly vertical pipe line extending through the roof, receiving the discharge of one or more water-closets with or without other fixtures.

Waste pipe: A pipe extending through the roof receiving the discharge from any fixtures except water-closets.

Vent pipe: A special pipe provided to ventilate the system of piping and to prevent trap siphonage and back pressure.

All the pipes of the system should be of extra heavy cast iron, and the diameters of pipes of the various kinds should not be less than as follows:

House drains, 4 inches; soil pipes, 4 inches; waste pipes, 2 inches; vent pipes, 2 inches.

All pipes should be water-tight and air-tight and all joints should be tightly calked with oakum and molten lead, the amount of lead required for a joint being about 12 ounces for each inch in the diameter of the pipe.

All changes in direction of both house-plumbing pipes and sewers should be made with one-eighth and one-sixteenth bends, not with quarter bends; and all connections of two pipes should be made with Y branches, never with T's.

As previously intimated, all soil and waste pipes should be carried vertically upward, beyond the highest fixture discharging into them to an open end above the roof in order to provide free outlet for all gases to the outside air.

To prevent foul gases from entering the buildings through the fixtures, every fixture should be separately provided with a water-sealing trap, placed as close to the fixture outlet as possible. The action of the trap is explained by reference to the diagrammatic representation of a U-trap shown in figure 5(a). The pipe A receives the liquid and solid wastes of a sink, basin, or water-closet, while the lower end, B, connects with the sewer. Foul gases rise in the pipe B, but are prevented from passing to the fixture by the water which stands in the trap.

In addition to its function as an outlet for the gases the vent pipe serves to prevent the destruction of the action of the trap by siphonage. This action is explained by reference to figure 5(b). When a considerable body of water rushes down through the pipe A, it forms a suction, and if the pipe is made air-tight, this suction is often sufficient to prevent enough water remaining in the trap to form a seal, thus leaving an opening for the passage of foul gases, as in figure 5. By connecting the upper bend of the trap with the outside air by means of the vent pipe V, figure 5(a), the suction will be stopped and the water in the pipe A will not fall below the level of the outlet at b.[1]

SEWAGE PURIFICATION AND DISPOSAL.

In temporary camps provided with running water, it will be satisfactory to drain the used water and sewage into a cesspool or pit, located if possible at a considerably lower elevation than the camp quarters, and at least 300 feet away from the well or water-source. The size of the cesspool will depend on the population of the camp and the character of the soil. In an impervious soil the dimensions of the pit should be large, else it will fill up rapidly and another will have to be dug. When the soil is light and porous enough to permit the liquid contents of the pool to run off through it, the filling up will be less rapid and the dimensions of the pool may be smaller. Cesspools always should be covered to confine the objectionable odors; and this may be done very simply by means of beams cov-

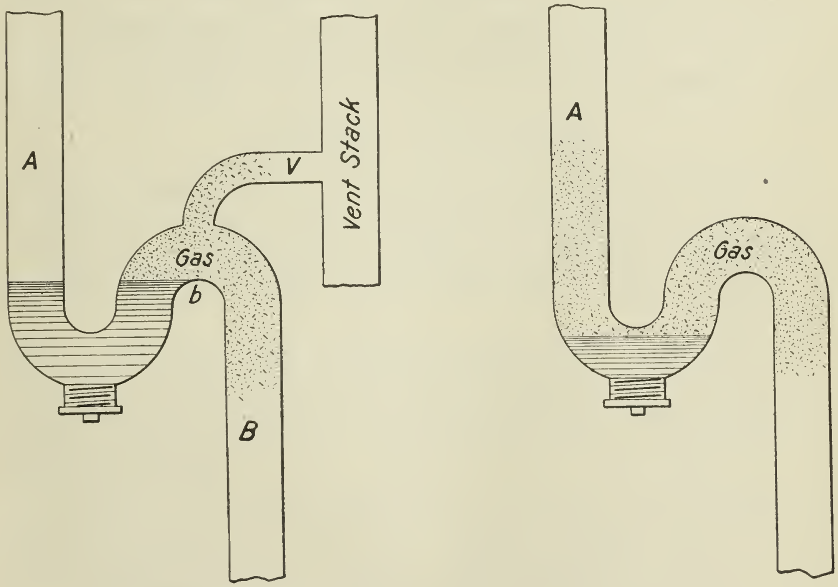

FIG. 5.—Explanation of the action of the U-trap and vent-pipe.

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[1] Kidder, "Architects' and Builders' Pocketbook," p. 1327.

ered by planks loosely laid, and these covered with 1 or 2 inches of earth from the excavation.

In large or permanent camps the problem of disposal is not so simple. For such camps, when they can not be connected with a city or town sewage system, purification of some sort must be provided. This may be effected by a septic tank for the preliminary treatment and ultimate disposal on the surface, by subsurface distribution, or by sand filtration. Such an installation usually will be found to be beyond the skill of the average official in charge of the camp and it will be advisable, in any case, to consult a reliable sanitary engineer. It will be required in so few camps and the details of the construction are of such a technical nature that no attempt will be made to enter into the subject here. It is treated as simply as possible in a previous bulletin of the department.[1] The department, through the Office of Public Roads and Rural Engineering, is prepared to give advice based on specific conditions on application.

METHODS OF GARBAGE DISPOSAL.

The following methods of garbage disposal, arranged in order of merit, were found in use in convict camps: (1) Incineration; (2) carting away by farmers; (3) burial; (4) dumping into covered pits; (5) feeding to hogs at the camp; (6) spreading over the surface of the ground.

The simplest of the foregoing methods is that of having the garbage hauled away by farmers, who, as a rule, are glad to take it for its value as hog feed. As it is also a matter of great convenience to the camp authorities to have the garbage removed at regular and frequent intervals, this method generally is used whenever the necessary arrangements can be made. Furthermore, if there be proper provision for the sanitary storage of the waste material for the time during which it necessarily must remain at the camp, there can be no objection to it from a sanitary standpoint. But as actually practiced in many of the camps visited the method of storage was very primitive. It was the custom, after each meal, to dump both liquid and solid garbage into one or two wooden barrels, usually placed from 100 to 200 feet from the main camp structures. Such containers are rarely cleaned or provided with covers and, standing open, their contents rapidly become sour and attract swarms of flies. The barrels swell and warp and allow the liquid garbage to leak through and saturate the ground; and they rapidly deteriorate, often to the point of falling apart altogether in the process of dumping. Much better containers, of metal with tight-fitting covers, can be purchased at almost any hardware store for a sum not exceeding $1.50. Such receptacles are water-tight and very serviceable, and when left covered remain free from flies and do not give off disagreeable odors. To prevent them from becoming unnecessarily foul they should be washed and scalded with boiling water at frequent intervals. As moisture is the immediate cause of souring, if the garbage be drained and wrapped in paper before being placed in the can it will not smell in hot weather, the can will not become dirty, and will not require emptying more than once or twice a week. This expedient will also prevent the garbage from freezing and sticking to the can in cold weather.

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[1] Bulletin No. 57, U. S. Department of Agriculture: "Water Supply, Plumbing, and Sewage Disposal for Country Homes." Copies of this bulletin may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents a copy.

At many camps, especially those in the South, garbage is collected in open pails in the kitchen and fed to hogs. The latter are oftentimes allowed to run loose around the camps and even have been seen inside the dining quarters of prisoners. The garbage is thrown into a trough or on the surface of the ground at some convenient spot not far from the kitchen door and left to the hogs to dispose of. Such primitive conditions should be tolerated no longer at any convict camp, and hogs, if kept at all, should be penned securely at a distance not less than one quarter of a mile from the camp.

Small, open garbage pails in the kitchens scarcely can be avoided, and are not objectionable if the kitchens are screened from flies and the pails emptied and cleaned after each meal. Camps have been seen, however, where the kitchens were not screened and garbage pails were hung at convenient angles on nails outside the kitchen windows. Most of the garbage dumped through the windows would fall into the pails, but some would drop down the sides of the buildings to the ground.

At many camps with plenty of vacant land surrounding them garbage is carried once a day to a spot 100 yards or more from the camp and water supply and is buried in shallow trenches. Under these conditions there can be no serious objection to this method of disposal. The trenches should be from 12 to 18 inches in depth and the garbage spread over the bottom in a layer about 2 inches thick and covered with earth immediately.

Garbage pits are in use at a few camps. They consist usually of a hole about 3 feet wide, 5 feet long, and 4 feet deep. The top is covered first with boards and then with earth, and a small trap door is constructed through which the garbage and slops are dumped. When the camp is moved the space which remains is filled with earth. Garbage pits are not as satisfactory as the shallow trenches already described. They are more liable to pollute the ground water, and their contents may remain in the ground unchanged for long periods of time and be uncovered by animals. They should be avoided whenever better methods of disposal are possible.

The disposal of garbage is accomplished in some instances by spreading it over the surface of the ground at a distance of 100 to 300 feet from the camp. The moisture evaporates rapidly in dry, hot weather and the remains, though unsightly, are greatly reduced in bulk and have but little odor. In damp weather, however, the garbage retains its moisture for a long time. It ferments and attracts large numbers of flies, and the odors are offensive for considerable distances. The rains wash it over the surface of the ground and may even carry some of it back to the camp, causing unpleasant odors and attracting flies. Under these conditions springs and wells are not free from danger of pollution. This method is, therefore, very unsatisfactory and should not be used.

Incineration.

Destruction by fire of both liquid and solid garbage wastes gives absolute security. Only one convict camp was encountered where an incinerator was in use, and in this case not only was garbage destroyed but all general camp wastes, including horse manure. The officers of the camp were enthusiastic over the results which had been attained by the use of the incinerator, the sanitary condition of the camp was excellent, and flies were few in number.

A very simple type of incinerator is constructed by digging a pit 5 feet long, 2½ feet wide, 6 inches deep at one end and 12 inches deep at the other. The pit is then filled with field stones upon which the fire is built, and the excavated earth is banked about the sides. After the stones have become thoroughly heated liquid wastes are poured into the pit at the shallow end. They come into contact with the hot stones at the bottom of the pit and are evaporated without quenching the fire. The solid wastes are placed on the fire where they soon dry out and burn as fuel. If stones are not available, tin cans may be substituted and used repeatedly. When neither stones nor cans are at hand a fire made in a pit of this character will destroy a considerable amount of garbage, both liquid and solid, but the use of stones or cans is preferable.

CALDWELL (OR ENGLISH) CREMATORY.[1]

Whenever fuel is scarce and stones few, this style of crematory may be improvised readily and is very efficient. It consists of a trench 10 feet long and 1 foot wide, about 15 inches deep at the middle and thence gradually shallowing up at each end to the surface level. Over the deep part, with one end resting on the edges of the trench, a barrel is placed, and around it clay, earth, or sod, sprinkled with water, is packed tightly. A fire is made in the interior and the barrel burned out, after which there remains a hollow cone of earth. Fuel and garbage are dropped down this chimney. Of the two openings in the trench at the bottom of the chimney the one to leeward is closed. A bed of tin cans in the fireplace makes a fair substitute for a grate. Every morning, or as often as necessary, the ashes and cans are raked out and a fresh fire started on a new bed of cans. If the soil is porous, a large quantity of liquids can be evaporated by pouring them into the trench slowly.

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[1] Havard, Valery, "Military Hygiene," pp. 654–655.

FOUR-OPENING CREMATORY.

A four-opening crematory may be made by digging two trenches bisecting each other at right angles. This has the great advantage of having one of the trenches always in the direction of the wind, and a good draft always can be secured by plugging the throats of the other trenches.

When two bisecting trenches are used the chimney is built over the point of the intersection, and four boards, flat stones, or pieces of sheet iron must be laid across the trenches for its support. If iron bars, old rails, or scrap iron are available they can be placed in so as to form a grate.

If a few pieces of corrugated roof metal are at hand they can be shaped easily into a serviceable chimney, thus saving time and labor.

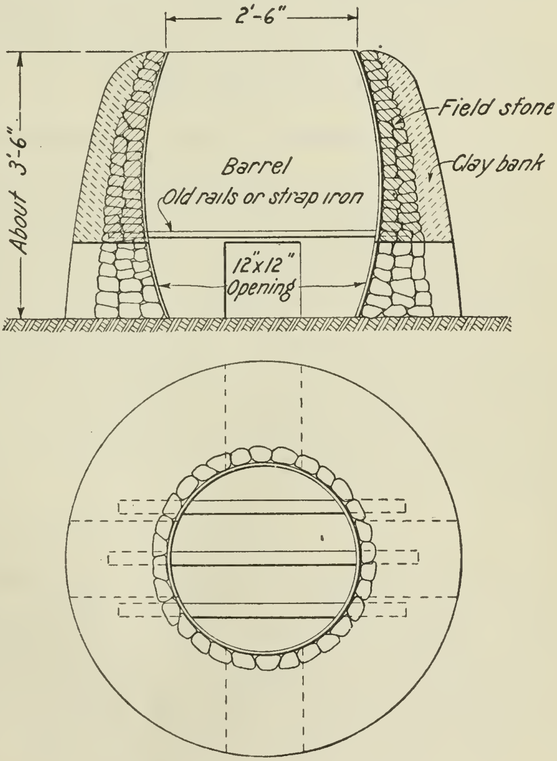

Fig. 6.—Barrel incinerator without trench.

BARREL INCINERATOR WITHOUT TRENCH.

This type of incinerator (fig. 6) may be constructed of field stones, as shown, or of fire brick. The stones or brick are built around a barrel, and laid in and covered with moist clay. When the clay has dried and hardened sufficiently to cement the stones the barrel may be burned out. An incinerator of this kind is suitable for a camp of 125 persons.

DISPOSAL OF GENERAL CAMP WASTES.

Metal receptacles with tightly fitting covers should be placed at convenient points about the camp and all waste materials placed in them. They should be emptied once each day and their contents disposed of by burning. The incinerators may be used to good advantage in this connection. Materials not entirely consumed by the fire should be buried. Tin cans always should be placed in the fire and then buried. If left on the surface of the ground with particles of food and moisture adhering to them, they may furnish breeding places for flies and mosquitoes.

Some one prisoner should be made responsible for the cleanliness of the camp grounds and their surroundings and daily inspection should be made by the camp authorities in order to see that wastes are properly collected and disposed of.

DISPOSAL OF BATH AND LAUNDRY WASTES.

Water which has come in contact with the body during the process of bathing, and that which has been used in washing dirty clothing, may contain the germs of any disease with which any person in the camp happens to be afflicted. In spite of this fact, however, it is a common custom to empty bath and laundry wastes on the surface of the ground in the vicinity of the camp structures, where they cause pollution of the soil and are unsightly and ill-smelling. Water-tight covered receptacles should be provided for all liquid wastes, which should then be evaporated in the incinerator, or carried 100 yards or more from the camp, poured into shallow trenches, and covered with earth.

FLIES AND MOSQUITOES.

In almost all convict camps flies and mosquitoes are present in such numbers as to be a veritable scourge. In general, only rather feeble attempts are made to get rid of them because the actual menace which they present, the conditions under which they breed, and effective methods for their destruction and prevention are understood but little by those in charge of camps.

Flies.

The danger of the transmission of disease by flies in particular can not be emphasized too strongly. They breed in and feed upon the filth of privies and manure piles and carry particles of it on their bodies and legs to kitchens and mess rooms, where they come into contact with and contaminate the food. In this way there is reason to believe that flies convey infection in such diseases as typhoid fever, cholera, dysentery, diarrhea, smallpox, hook-worm disease, tuberculosis, measles. scarlet fever, diphtheria, skin infections, and many others.

It has been found that a single fly may carry more than 6,000,000 germs on the outside of its body and as many as 28,000,000 in its intestinal canal. What it means, therefore, to have a fly fall into milk or other liquid food is seen readily.

The suppression of flies at convict camps can be successfully accomplished only by doing away with their breeding places. Screens, flytraps, sticky fly paper, and poisons all are useful in waging war against them but are not, in themselves, sufficient. The fundamental rule which should be enforced rigidly is that of absolute cleanliness of the camp and its surroundings. Human excreta, garbage, and other wastes must be protected from flies by methods described under paragraphs dealing with those subjects, and such breeding places as stables, chicken yards, and hogpens should be removed as far as possible from the main structures. As flies seldom travel more than 500 yards from their breeding places, it follows that if the mess and living quarters be separated from such places by at least that distance immunity from flies will be practically assured. But it is usually impracticable to locate the stable at such a remote distance, and, since piles of manure are favorite breeding places, special measures must be adopted for their disposal or treatment. The most practical of such measures are outlined as follows:

(1) The manure may be placed in covered barrels each morning for removal by farmers at least twice a week, and the polluted ground about corrals may be sprinkled with kerosene; (2) the manure may be burned in an incinerator; (3) the borax treatment: Apply 0.62 pound borax, or 0.75 pound calcined colemanite, to every 10 cubic feet (8 bushels) of manure immediately on its removal from the barn. Apply the borax with a flour sifter or any fine sieve, particularly around the outer edges of the pile, and sprinkle 2 or 3 gallons of water over the borax-treated manure.[1] With regard to the effect of this treatment upon the value of the manure as a fertilizer, it is recommended that not more than 15 tons of the borax-treated manure be applied to an acre, as its effect has not been studied in connection with all crops. With borax at from 5 to 6 cents per pound the cost of the treatment will be about 1 cent per horse per day, and if calcined colemanite be purchased in large quantities the cost should be considerably less; (4) the hellebore treatment: Apply to every 10 cubic feet (8 bushels) of manure a mixture of one-half pound of powdered hellebore in 10 gallons of water. As in the case of the borax treatment, special attention should be given to the outer edges of the pile. This treatment is somewhat more expensive than the borax treatment, the estimated cost per horse per day

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[1] Bulletin No. 118, U. S. Department of Agriculture: "Experiments in the Destruction of Fly Larvæ in Horse Manure." Bulletin No. 245, "Further Experiments in the Destruction of Fly Larvæ in Horse Manure."

being about 1.4 cents. But it has the distinct advantage of not affecting the fertilizing value of the manure even when used in excessive amounts.

MOSQUITOES.

It is now definitely known that in nature malaria is transmitted only by the sting of certain species of mosquitoes, and the most successful means of avoiding this disease is to provide protection from mosquitoes.

When convict camps are located for an entire summer season in regions where mosquitoes abound, it may be found profitable to strike at the mosquitoes by destroying their breeding places in so far as this is practicable.[1] The antimosquito measures generally employed are briefly described by the United States Public Health Service as follows:

> (*a*) Regrading and training of streams, creeks, or similar natural water courses so as to favor a free current.
>
> The shallow grass-grown margins of streams, ponds, or any bodies of water must be cleared and the banks made with a clear-cut edge in order that any top-feeding minnows present may have a clear field for their activity and that this field may be extended.
>
> (*b*) Drainage for the removal of standing water or to produce a movement of water unfavorable to mosquito breeding. Ditches should be as few and as short as possible and so constructed that any water present will be confined to a narrow channel. Open ditches must be kept free of grass, débris, or any other obstructions. They may be made permanent and easy of maintenance by lining with cement, stone, or wood.
>
> Ditches as ordinarily used should have a bottom not over 8 inches wide and the sides sloping.
>
> Subsoil tile drains, while more costly, are more effective.
>
> (*c*) Filling in of places which are too low to drain or which can not be drained economically. For this purpose any available porous material, such as ashes, sawdust, or shavings, may be employed. When using sawdust or shavings, such material should extend 6 inches or more above high water which follows a heavy rain.
>
> (*d*) Oiling and larvicides. Oil may be applied by the use of (1) a garden watering-pot; (2) a knapsack sprayer; (3) a drip can for intermittent or continuous oiling regulated to deliver 18 to 20 drops of oil per minute. The bottom of the drip can should be about 4 feet above the level of the water surface; (4) an oil-saturated bundle of cotton waste. This is to be anchored into place and will serve for about one week. (*e*) Natural enemies. Stocking with top-feeding minnows is a measure applicable in certain ditches, ponds, swamps, streams, and many other bodies of water.

For camps which change their location every few weeks the foregoing measures may be too elaborate for use. It should be remembered, however, that mosquitoes can not live in the hot sun and that the clearing away of high grass and underbrush from the surroundings of the camp will aid materially in diminishing their number. All barrels and tubs used for the storage of water should be covered tightly with thicknesses of burlap, sheeting, or cheesecloth, held in place by well-fitting hoops, and should be fitted with spigots so that they need not be uncovered except for cleaning and filling. Wooden covers are not satisfactory, as they do not fit tightly enough to keep out mosquitoes and are liable to warp. Cesspools and privies must be constructed in such manner as to prevent access of mosquitoes, while tin cans, broken bottles, sagging gutters, holes in rocks, hollows in trees, or any other places which may hold water and serve as breeding places for mosquitoes, should not be allowed to remain about a camp. Areas of stagnant water, when they can not be drained, should be treated once every ten days with a half and half mixture of crude oil and kerosene.

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[1] Reprint No. 272, From the Public Health Reports, U. S. Public Health Service, Apr. 30, 1915.

Screens and mosquito bars are indispensable in keeping out mosquitoes wherever they are prevalent, and in some places both screens and bars will be found necessary. At those camps in which steel convict cages are in use screening is comparatively simple and inexpensive, and satisfactory results are obtained by carefully screening the four open sides. Experience has shown that mosquitoes can sometimes pass through a metal-wire screen containing 16 strands or 15 meshes to the inch, but can not pass through one which contains 20 strands or 19 meshes to the inch.[1] Screens made of iron wire are cheapest at first cost, but require painting in order to make them last through a season. The paint reduces the size of the mesh, so that ventilation is interfered with to a considerable extent. On the other hand, screens of brass or copper last almost indefinitely and though expensive at first may be cheapest in the end.

Mosquito bars are well adapted for camp use and should be a part of the regular equipment in regions where mosquitoes are numerous. They may be suspended from the ceiling and tucked in around bunks or may be arranged so as to rest upon the floor all around the bed.

VOLATILE OILS.

Oil of citronella, oil of pennyroyal, and similar substances are used frequently to rub on the face and hands and to place on the bedclothes at night, and have some effect in keeping away mosquitoes. They evaporate rapidly, however, so that their benefits are only temporary. None of them will last through the night.

ISOLATION AND PROTECTION OF PERSONS SUFFERING WITH MALARIA.

Any prisoner who is suffering with symptoms which may reasonably be ascribed to malaria should be isolated at once and carefully protected from mosquitoes by mosquito bars. This will prevent mosquitoes which are not infected from biting the patient and so becoming infected and capable of transmitting the disease to others. Mosquitoes can not transmit malaria without first biting a person who has the disease in his system, so the importance of this method of prevention is apparent.

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[1] Rosenau, "Preventative Medicine and Hygiene," p. 205.

PREVENTION OF MALARIA BY THE DAILY ADMINISTRATION OF SMALL QUANTITIES OF QUININE.

This method of preventing malaria often may be useful in camps which are established in malarial regions for short periods of time, but it does not take the place of measures for mosquito suppression. From 2 to 3 grains of quinine sulphate daily is the generally accepted amount and often accomplishes good results.

SANITATION OF QUARTERS.

Overcrowding of Sleeping Quarters.

The quarters of a few permanent camps visited were so arranged as to provide space enough between the rows of bunks for chairs and reading tables; but in the great majority of camps visited the sleeping quarters were badly overcrowded, the general rule being to squeeze in as many men as the structures could be made to accommodate. At some of the camps there were no spaces whatever between the beds, and the faces of the sleeping inmates could never be more than 30 inches apart and might be in actual contact, a condition highly favorable to the spread of communicable diseases. In other cases men were crowded into shacks or tents in triple-deck bunks, or bunks of double width for two men were placed side by side or in double tiers, and other camps were seen in which all the regular bunks were occupied and extra ones were provided by placing mattresses over boards laid across beams at the level of the eaves, so that the men slept in the space formed by the pitch of the roof.

The worst cases of overcrowding occur in the cages which are sometimes used for housing convicts. These cages, mounted on wheels, are from 7 to 8 feet in width and height and from 12 to 18 feet in length and closely resemble the cages in which wild animals are driven through the streets in a circus parade. They are fitted with bunks in three tiers which extend along both sides of the cage, leaving an isle 2 or 3 feet wide down the middle. The bunks are 2½ feet in width and 6 feet long, so that 18 men can ordinarily be placed in a cage 18 feet long. A cage was seen in which two men slept in each single bunk, an example of overcrowding scarcely to be imagined. In this instance 49 cubic feet of air space and 7 square feet of floor space was the allowance which each man would receive if the cage were entirely unfurnished, but the actual space was considerably less, owing to the presence of a stove, toilet seat, bunks, and bedding. This particular cage in its original construction had a steel grating on both sides, so that the air could circulate freely through it, but when observed the entire cage had been inclosed in a tight casing of matched boards. There were two windows 1 foot wide by 1½ feet long on both sides of the cage and four such windows on one end. Every window was tightly shut and some were firmly fastened by strips of wood nailed across on the outside. The only permanent openings were the ones in the floor under the toilet seat and the one in the roof for the stovepipe. Add to the details already presented a dark and dirty interior alive with vermin, blankets indescribably foul and filthy, and a hole underneath filled with uncovered, unprotected human filth, and the picture is complete.

While this condition is the worst which the investigation revealed, many other overcrowded, dirty, vermin-ridden wooden cages were found in use. The steel cages can be kept free from vermin, but, as seen in actual use, they are badly overcrowded and tightly closed on all sides at night by the canvas curtains with which they are provided.

Proper Space Allowance.

The question of the exact number of persons which may properly be assigned to a given space is one which is difficult to answer. It is reasonable to assume, however, that the space in the sleeping quarters of any camp should be sufficiently large to permit a healthful separation of the occupants and to allow the body all necessary freedom of motion. As the result of observations of many convict camps and with a knowledge of the economic problems with which they are confronted, the conclusion has been reached that an allowance of 20 square feet of floor space for each man and a distance of 2 feet between beds or bunks (which should be single) is the least that can be provided without serious overcrowding. The separation of the beds and economy of floor space may be obtained by the use of double-deck bunks. The bunks should be set out a foot or more from the walls of the building, in order to allow a free circulation of air on all sides.

Ventilation.

When human beings are inclosed in a space not provided with adequate means for the entrance of fresh air and the escape of stale air, the atmosphere may become overheated, overmoist, and stagnant, and experience has shown that this is an extremely unhealthful condition in which to live. Not only is the working power diminished, but the vitality of the body and its ability to resist disease also are impaired.

In the winter persons who live in overheated rooms filled with stagnant air made moist by the breath and excretions of the skin are especially susceptible to coughs, colds, pneumonia, and other diseases of respiration which could be avoided to a great extent by good ventilation. In summer, when even the outdoor air is often hot and moist, the thorough ventilation of living quarters will prevent indoor conditions from being many times worse.

From recent experimental evidence it appears reasonable to conclude that the bad effects of stale air are due to the heat and moisture which it contains and permits to cling around the body, forming what has been called an "aerial blanket." "The breaking up of this zone of concentrated discomfort by circulation of the air is a most important factor in good ventilation."[1]

The regulation of air space alone can be of little value. No matter how large the space, the atmosphere may become stagnant, moist, and overheated, and however small the space, the temperature and humidity may be kept within healthful limits.

The temperature at which the body may best be maintained under ordinary conditions has been found to range between 66° and 70° F., and the problem of ventilating convict camps resolves itself into one of keeping the temperature as nearly within these limits as possible during the winter months and in making inside conditions as nearly as possible like those out of doors in the summer months. This may best be accomplished by making several small inlets for fresh, cool air in both sides of the building at the level of the floor and providing outlets for the heated air in the roof, preferably along the ridge. Ventilating openings should always be screened. The size and number of ventilating openings should depend upon the size and shape of the room, and no general statement will apply under all circumstances. In a large apartment it is usually better to provide a number of small openings for the incoming air rather than one large one, and the same is true of outlet openings.

An excellent type of structure for summer use is that in which the sides and one or both ends are open and protected by screens for a space of 3 or 4 feet in width all the way around .

Tents and other structures whose sides are inclosed only with canvas curtains receive a considerable amount of air which passes through the pores of the canvas, but when the temperature of the inside and outside air is about the same, and in wet weather when the pores become closed by the swelling of the canvas, the ventilation may be bad, and openings should always be provided at the ridge. Types of poorly ventilated quarters are shown in Plate V, figures 1 and 2.

HEATING.

Almost all convict camps use wood-burning stoves for heating purposes and find the method generally satisfactory. The stoves are placed as near as practicable to the center of the room, or distributed along the aisles when more than one is required. At one camp of a somewhat permanent character a complete hot-water heating system had been installed. The boiler was located in a covered concrete pit outside the bunk house and was large enough to furnish an ample supply of hot water for shower baths and washbasins.

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[1] Winslow, C. E. A.

One large camp under canvas obtained very satisfactory results in heating the tents by using stoves consisting only of a cone of sheet iron with a grate at the base and a stovepipe fitted to the upper end. There is a door in one side and the ground is hollowed out slightly so as to allow the air access to the grate from underneath. The cost of these stoves is about $3 each.

LIGHTING.

Light usually is provided by lanterns and small oil lamps, but camps occasionally are seen in which large drop-lights are furnished for reading purposes. Many camps are located so that electric lights are possible.

SANITARY PROVISIONS FOR THE KEEPING OF EXTRA CLOTHING.

At many camps pigeonholes or shelves for the keeping of extra articles of clothing are furnished in a space set apart expressly for that purpose. This space may be in the laundry shed or tent, or it may be a part of the storeroom. Small boxes in which the prisoners may keep letters, toilet articles, and small personal belongings generally are nailed to the walls at the head of each bunk. Camps with facilities such as these can be kept in a neat and orderly condition and are cleaned readily. Unfortunately, however, there are camps where all the clothing of the prisoners must be kept in the already overcrowded bunk houses. Boxes filled with clothing and other possessions are placed on the floor under the bunks; articles of every description are suspended from hooks and nails driven into the framework of the structures; and ropes and twine upon which to hang objects which can not be disposed of elsewhere are strung about the room. Many things are placed on the bunks in the daytime and under the mattresses or on the floors at night. Not only do quarters thus cluttered present an extremely disorderly appearance, but the free circulation of air is prevented, valuable space is taken up, the articles collect dust and dirt, and proper cleaning is made extremely difficult.

CLEANING OF BUNK HOUSES.

Most of the dust and dirt which finds its way into the bunk houses is carried in on the feet and may be reduced greatly by the use of scrapers and metallic mats at the doors. In addition to the mud and dirt, the floors also receive sputum, fragments of food, and other organic débris shaken from the clothing and bedding. These impurities, when dry and ground into a fine dust under the feet of the occupants, are set in motion by air currents, scattered widely over all the objects in the room, and breathed in with the air. Ordinary dry sweeping stirs up a great deal of dust which settles again over the same or different parts of the room and meanwhile pollutes the air. This method of sweeping, therefore, is worse than none at all. The proper method of cleaning floors is by using a damp mop, not by sweeping. The mop should be dipped in a bucket of water, wrung out, rubbed on the floor, then washed and rinsed in another bucket of water. The method of cleaning floors by flooding them with water and then scrubbing and sweeping is bad, because the dampness promotes the growth of bacteria and the water gets into the holes and fissures, causing the wood to warp and crack.

A practice by which much labor in sweeping and scrubbing may be saved is that of coating the floors of bunk houses with an oil floor dressing. The particles of dust adhere to the dressing, but may be removed easily by sweeping, because they are too heavy to rise and float in the air.

Such a dressing preserves the wood and tends to keep out vermin and insects. Oil dressings for this purpose are well known and extensively used and may be purchased through almost any hardware store. The price ranges from 20 to 30 cents a gallon in 1-barrel lots, containing from 50 to 53 gallons. It is also possible to purchase the dressing in 5-gallon lots, but at a higher price. One gallon properly applied will cover about 600 square feet of floor space, and a single application is said to be effective for two or three months.

SPITTOONS.

Spittoons are used in some camps, but not in all. In many cases boxes filled with sawdust are provided, and the contents are burned each day. Such boxes, while far better than nothing, are almost impossible to clean and disinfect, and while being dumped on the fire the sawdust contaminated with sputum is often caught by the wind and scattered broadcast about the camp. A much better receptacle for the sputum is a metal or fiber spittoon which rests firmly on the floor and has a wide opening to permit easy cleaning. Spittoons should be removed each day to the place where other excreta are disposed of and cleaned, preferably with boiling water, then partially filled with a disinfecting solution. Since, without the knowledge of the men who eject it, sputum may contain the germs of tuberculosis, diphtheria, pneumonia, and many other diseases, rules against promiscuous spitting about the camp and in the quarters should be enforced rigidly.

VERMIN.

Convict camps are especially liable to vermin infestation, and constant care and watchfulness are necessary to keep the quarters free. The bathing of all incoming prisoners and disinfection of their cloth-

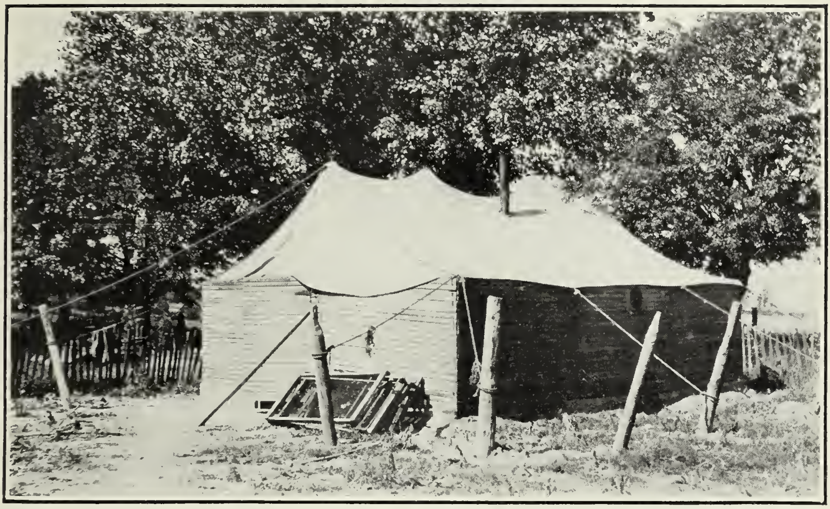
OPRRE11699

FIG. 1.—POORLY VENTILATED TEMPORARY SHACK.

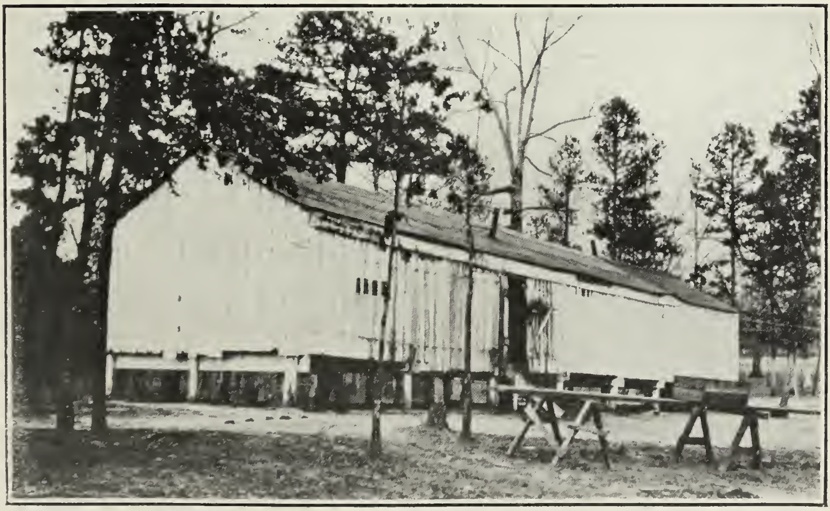
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FIG. 2.—POORLY VENTILATED PERMANENT QUARTERS.

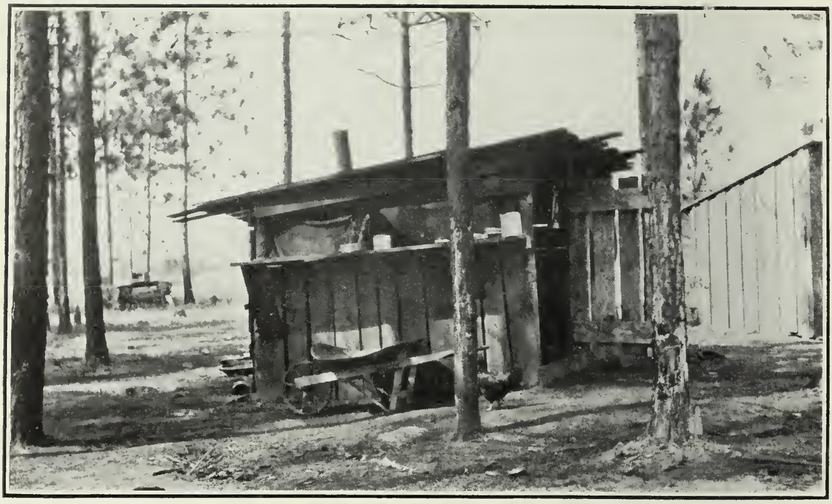

FIG. 1.—RAMSHACKLE AND INSANITARY KITCHEN.

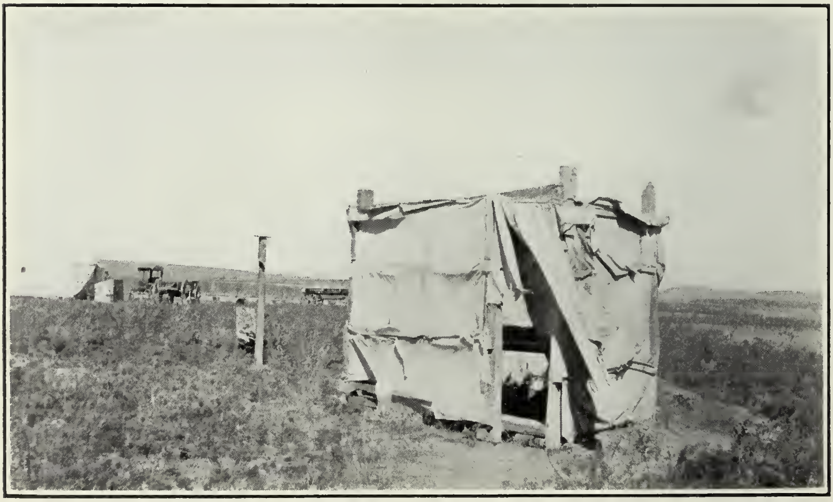

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FIG. 2.—INSANITARY PRIVY.

ing, as recommended elsewhere, is the surest means of preventing the introduction of vermin, but even at camps where every precaution is taken infestation may occur. It has been said that the guards sometimes bring vermin to a camp after returning from leave of absence.

The bedbug, or "chinch," is the commonest of the camp vermin, although the body louse is encountered sometimes. Bedbugs are particularly difficult to control in the wooden convict cages and in those camps in which the bunks are made of wood. They thrive under filthy conditions. They secrete themselves in cracks and crevices in the wood and have been dug out of holes made by nail heads deeply driven. At convict camps where folding Army cots had been in use it was stated that the bugs were found frequently between the canvas and the wooden frames.

Bugs may be eradicated by spraying or painting the crevices and cracks of woodwork with kerosene, gasoline, oil of turpentine, or corrosive sublimate solution in 1 to 1,000 dilution. The superficial spraying or sprinkling of floors and bedclothes with formalin or other disinfecting solutions is absolutely useless, although it is a favorite camp method for combating almost every evil resulting from dirt and neglect.

Sulphur fumigation is a very cheap and effective method of destroying vermin and insects of all kinds. When this is to be used, every crack and opening in the building must be closed by strips of newspaper smeared with flour paste. Chimney openings and keyholes should not be overlooked. Sulphur, in the proportion of 2 pounds for every 1,000 cubic feet of air space in the building, should be broken into small pieces and placed in a shallow vessel, preferably of iron. The dish should have a wide opening so that as large a surface of sulphur as possible may be exposed to the air in order to favor combustion. In a large building it is well to distribute the sulphur about the space in several pots. To avoid danger of fire, the pot containing the sulphur should be placed in a large metal receptacle, such as a metal washtub, with a few inches of water in the bottom of the latter. The whole should then be supported 3 or 4 inches above the floor by means of two pieces of wood, pipe, or other convenient material. When the sulphur pots and pans are all in place and all openings are pasted up securely except the one exit for the man who is to fire the sulphur, the operator, beginning with the pot farthest from the door, should pour into each sulphur pot about half a cup of wood alcohol or denatured alcohol from a closed can (the ordinary kerosene oil can is safest), and then throw in a lighted match. After he has lighted all the pots and withdrawn, the exit should be closed tightly and strips of paper pasted outside over the cracks between the door and the frame. The building should remain closed for at least 10 hours, and longer if possible. Doors and windows should then be thrown open and the building aired thoroughly. Sulphur gas corrodes metal, and, where moisture is present, injures fabrics, often fading and rotting them. Blankets and clothing should therefore be removed from bunk houses before fumigation takes place and beaten out and sunned for several hours. If the fumigation is done on a day when the atmosphere is dry, however, and safeguarding from fire can be accomplished without the use of water in the pans, then blankets and clothing may be exposed to the fumes to advantage and without fear of injury. Sulphur fumes are just as destructive to insects and vermin in a dry as in a moist atmosphere. Metal cooking and eating utensils, and all food supplies, should be removed before fumigation. Any polished metal that can not be taken out may be protected by smearing vaseline over it.

KITCHEN AND MESS QUARTERS.

In camps of the better sort the kitchen and mess quarters are well constructed and the kitchen, at least, floored. Doors and windows are screened properly, flytraps are in use both inside and outside the quarters, and the condition of tables, benches, and cooking and eating equipment compares favorably with conditions found in the average household. But at some camps, mess rooms and kitchens are in a frightfully insanitary condition. The structures themselves are sometimes miserable, ramshackle huts, as shown in Plate VI, figure 1, and both space and facilities are so limited that any attempt at order or cleanliness is out of the question. Frequently unfloored, the ground within the kitchens in particular becomes muddy from slops spilled accidentally, and fragments of food litter the tables and the ground. Flies swarm over the food and around the sour, open garbage pail, which usually occupies a position just outside the door. Frequently a mess room is not provided in this type of camp, and after receiving their pans of food at the kitchen window the prisoners seat themselves about the camp grounds on stumps or any other objects which can be made to serve the purpose. In bad weather they eat while sitting on their bunks.

At several camps visited dining tables and benches were placed under canvas awnings or shelters of frame construction, and sometimes a wooden flooring was provided. Such an arrangement may be made to have a very neat and attractive appearance, as shown in Plate VII, figure 1, and is far preferable to a dirty, overcrowded space in a frame structure or tent. However, dining shelters of this type can not be used except where the climate is warm and dry.

There are many camps where an attempt has been made to screen the dining room and kitchen, but where the flies seem quite as numerous as in structures not screened at all. The lack of success is due largely to the carelessness of the kitchen force, which allows the screen doors to remain open much longer than is necessary. Screen doors should be provided with firm springs in order to keep them closed, and knot holes and all other spaces in the walls of the dining room and kitchen must be stopped if flies are to be kept out.

At camps in which the responsibility for keeping these quarters neat and clean is placed upon one man much better results are attained than is the case when the kitchen force in general is supposed to attend to this duty. The kitchen and dining room should be cleaned thoroughly at least once a week and the floors should be mopped daily.

Tables should be brushed after each meal, scrubbed with soap and hot water, rinsed with clean water, and dried. Saltcellars, pepper boxes, vinegar cruets, mustard pots, and sugar bowls should be wiped with a dry cloth after each meal, and care should be taken to see that they are filled properly.

Dishes should be washed first in water in which there is plenty of soap and should then be scalded. Flatware—knives, forks, spoons—should be washed clean in a separate pan, and then scalded and wiped dry. The scalding of dishes and flatware is of great importance and never must be omitted; otherwise there is danger of infectious diseases being carried from one person to another.

HEALTH CONDITIONS AND CARE OF SICK AND INJURED.

Complete physical examinations are seldom made at the time the men are sent to the road camps. Prisoners are examined upon their admission to the penitentiaries and their records thereafter are known in a general way to the prison physicians. If they have not been sick during their stay in the prison they generally are considered as being in good physical condition. In some States the only necessary qualification is that the men shall apparently be able to work. When the men enter the camps under these conditions, the ones who are able to work do so and the others are sent to the State farms or county hospitals for treatment. It is not intended that prisoners suffering from venereal diseases should be permitted to enter the road camps, but in the vast majority of camps visited venereal diseases were not entirely absent.

PHYSICAL CONDITIONS OF CONVICTS IN CAMPS AND DISEASES PRESENT.

The physical condition of the convicts employed on road work depends very largely upon the care which has been used in their selection and the motives which have actuated physicians and wardens in their choice. Camps in which the main purpose is to accomplish the greatest possible amount of work usually are composed of stalwart laboring men in the prime of life, well suited in every way to do the work they are called upon to perform. Other camps, especially those operated under the honor system, are more representative of the convict class as a whole and are composed of men of all ages and from many different walks of life. Prisoners over 60 years of age are not infrequently seen at work on the roads, but since it is generally recognized that they are not able to do as much work as younger men, allowances are made and they are permitted to remain so long as they show a willing spirit and conduct themselves in a proper manner. Others not at all accustomed to hard manual labor also are employed on the roads, but are neither required nor expected to measure up to the standard of more experienced laborers. A cheerful attitude toward the work and a disposition to abide by the rules of the camp are the principal requirements.

In the Eastern and Western States very few diseases are found among the prisoners in the camps. It is rather common to find one or two cases of chronic gonorrhea in camps consisting of from 50 to 100 white prisoners, and several cases with a history of syphilis, but without clinical symptoms, usually can be found by questioning. Serious illnesses are very few and it is seldom that a prisoner is obliged to lay off for more than one or two days at a time.

Two camps were found in which cases of typhoid fever had occurred. In each instance it was definitely ascertained that the disease had resulted from the drinking of polluted water outside of the camp supply. At both camps prisoners were warned against drinking water from unknown sources and in addition to this each man received the antityphoid inoculation. In one State, all persons who were admitted to the penitentiary were vaccinated for smallpox and received the antityphoid inoculation, but in general neither the convicts in the penitentiaries nor those in road camps undergo either of these treatments.

In the southern camps, where a large majority of the convicts are negroes, venereal diseases are extremely prevalent and in most cases no attempt is made to prevent prisoners with these afflictions from entering the camps. Superintendents of negro camps admit freely that many of their men are suffering from venereal diseases in one form or another and that they are greatly hampered in their work from this cause. Mercury and potassium iodide always are kept in stock and negroes showing symptoms of syphilis receive sufficient treatment to enable them to keep at their work. In certain camps negro convicts have been seen with fever, headache, mucous patches in the throat, pains in the bones, and syphilitic scars and ulcerations on the body, and it is said that convicts frequently are sent to the camps in this condition and that it is useless to return them for treatment because other cases as bad or worse may be sent in exchange. It is a common custom when prisoners are transferred from one camp to another for the superintendent to choose his syphilitics to send to the next camp. Superintendents say that they try to keep the washbasins, towels, and dishes of such prisoners separate from the rest, but it is almost impossible to care properly for syphilitics in a camp and they never should be sent there.

Hookworm disease is found frequently among convicts in the South. One physician stated that 15 out of 17 convicts whom he had examined at one camp were infected with hookworm. No attempt is made to cure such cases.

Pellagra was found at only one camp, the others being remarkably free from this disease.

Cases of tuberculosis are not infrequently discovered in the negro camps but, as a rule, are sent immediately to the State or county hospitals for treatment.

The daily sick rate at 40 camps in different parts of the country was found to vary from less than 1 per cent to 6 per cent. This variation is attributable to a number of different factors. Many men who report themselves sick are suffering from slight indispositions with vague and indefinite symptoms which lay them up for a day or two. Others are incapacitated temporarily by sore muscles, lame backs, boils, and minor cuts and bruises. Disturbances of digestion, due to overeating, are rather common among men entering the camps after long terms in the prisons. Such cases occur much more frequently at the camps where a good variety of appetizing food is served. An epidemic of coughs and colds or influenza increases the average sick rate of a camp very materially. It happens not infrequently that a prisoner may receive an injury which incapacitates him for work for several weeks. Under ordinary conditions such a man is returned to the prison and a substitute is sent, but at honor camps a man recovering from an injury often is kept at the camp because it is considered a hardship to return him to the prison and because the life outside will hasten his recovery. Cases have been encountered where men were kept at the camps even though they were obliged to remain on the sick list for six weeks or longer, although this humane treatment entails a high sick rate.

In States where the examination of prisoners is lax, men subject to frequent attacks of illness such as rheumatism, tonsilitis, hemorrhoids, and boils may be sent to remote camps. They are able to work only a part of the time and yet are kept at the camps because of the expense and inconvenience of returning them to the prisons. This practice increases the sick rate but is no fault of the camp authorities.

Cases of pretended sickness occur occasionally at practically all convict camps. The personality of the superintendent of the camp is of great importance in preventing this difficulty and instances have been observed where a change of superintendents resulted in an immediate decrease of 50 per cent in the daily number of men sick.

ARRANGEMENTS WITH PHYSICIANS FOR THE TREATMENT OF CONVICTS IN ROAD CAMPS.

All convict camps have arrangements whereby the services of physicians may be secured when necessary. The methods of securing medical and surgical aid vary in different camps and under different conditions and are as follows:

Treatment by Prison Physicians.

When camps are located within a reasonable distance of the State penitentiary, medical and surgical treatment always is furnished by the prison physicians so that the camp is under no extra expense for medical care. The prison physicians make visits to the camp at regular intervals, and, in addition to prescribing treatment, give advice regarding the sanitary upkeep of the camps. This is an excellent arrangement and the results are very satisfactory.

Treatment by State Medical Officers.

In the State of Florida two physicians are employed at salaries of $1,800 per year, who devote their entire time to visiting all camps in which State convicts are employed. They examine prisoners who report themselves sick and prescribe treatment at the camp or order them to be sent to the hospital at the State farm if their illnesses are such as to incapacitate them for work. They also inspect the camps to see that they are kept in proper sanitary condition and supervise the feeding of the men. Each camp is visited by one of these physicians about once in every three weeks. In the meantime a local physician is employed to see that orders are carried out and to take charge in emergencies.

Treatment by County Physicians.

County convict camps usually are under the supervision of the county physicians. The camp duties of these officers are a usual part of their regular work and extra salaries are seldom paid therefor. County physicians sometimes visit camps at regular intervals and also advise as to the methods of sanitation to be employed, but more often they do not visit the camp unless they receive special calls.

Treatment by Contract With Local Physicians.

Many camps in which State prisoners are employed, enter into monthly contracts with local physicians by which the latter agree to furnish whatever medical and surgical treatment may be necessary. The contract prices range from $25 to $50 per month and in some cases the price is set at $1 per month per man. In rare instances contract physicians visit the camps in their charge once every day, but more often they come only when called and in many camps the calls do not average more than three or four a month.

Treatment by Local Physicians Paid by the State.

At some camps it is deemed expedient to employ local physicians at a fixed price for each visit they are called upon to make. The price ranges from $2 to $5 a visit, depending upon the distance to be traveled. This is an economical arrangement when the sick rate is low and when serious injuries are few.

FACILITIES FOR THE CARE OF SICK AND INJURED AT THE CAMP.

It is not intended that prisoners with infectious diseases or otherwise seriously sick or injured shall remain at the camp. Such men are transferred immediately to prison, county, or State farm hospitals as soon as they have been seen by a physician. Only two camps were provided with rooms for the isolation of prisoners who were sick. But at one other camp any man who reported himself sick was kept apart from the other prisoners and fed on a short ration as a matter of policy. The superintendent believed that fewer men complained of being ill and that recovery was more rapid when this method was employed.

One of the New York honor camps, with a population of about 60 men from Sing Sing prison, was provided with a two-room hospital. One room was fitted out as a sort of out-patient department where medicines were stored and dispensed and where the records were kept, and an adjoining room contained two beds and was useful both as an examination room and for isolating sick cases.

Prisoners who are not sick enough to be removed from the camp remain in their bunks in the general sleeping quarters, and in cases where bunks of double width are provided, the sick man is obliged to share the space with his partner. In the camps where the sleeping men are so close to one another as to be in actual contact any disease of an infectious character may be conveyed readily from one to another.

Many camps are well equipped with first-aid outfits and a few simple remedies, and some person at the camp, either the superintendent or foreman or one of the prisoners, frequently has had enough experience to enable him to render first aid to the injured and to administer medicine. In some States camp superintendents receive a short course of training in first-aid requirements from the prison physicians. In other States no medical or surgical supplies are furnished and those in charge of the camps purchase medicine and bandages at their own expense so that they may be able to give some relief before the arrival of a doctor.

While serious accidents occur only rarely, it would appear nevertheless that every camp outfit ought to be prepared to meet any emergency. At one of the camps visited it was recorded that a convict had received a compound fracture of the thigh from being struck with a piece of flying rock and at another, one of the prisoners received an injury which resulted in the loss of one hand. Both of these cases were cared for successfully at the camps until the services of a physician could be secured. Practically all of the camps were provided with telephones and were so located that medical aid could be procured within a reasonable time.

DISCUSSION AND RECOMMENDATIONS.

Benefits Derived from Outdoor Work.

Camp life and out-of-door work without doubt are far more healthful and beneficial than life behind prison walls and are sought eagerly by prisoners. The best results are being accomplished at those camps where the men are not selected for the sole purpose of constructing a road, but where the first consideration is the good which may be derived by the men themselves. Prisoners who have proved themselves worthy of trust are among those upon whom it would appear especially fitting to bestow the benefits and advantages of outdoor life and exercise.

While it is a fact that diseased men should not be sent to the camp, it is true also that certain of the less robust individuals can be developed and benefited greatly by the opportunities which the camps afford. It is very possible that mental and physical breakdowns often could be avoided in such a way as this, and it would appear a small matter, indeed, if the number of days lost on account of minor ailments should remain somewhat above the average for the first few weeks if the men themselves eventually were benefited and strengthened. At camps where the welfare of the men is borne in mind, there is no disposition on the part of the officers to require more than they can reasonably do, and the attitude of both keepers and men is that of a "square deal" all around.

Physical Examinations.

The importance of thorough physical examinations by competent physicians scarcely can be overestimated. It is only in this way that men suffering from infectious diseases can be prevented from entering the camp and becoming a menace to the health of the entire force. Those suffering from heart disease, Bright's disease, hernia, and similar afflictions may also be detected, thereby protecting the individuals from possible serious injury and saving the camp much needless trouble and expense. The physical examination should be conducted as shortly before sending the man to camp as practicable.

Cooks and others having to do with preparation of food should receive a special laboratory examination to insure that they are not typhoid carriers.

Vaccination and antityphoid inoculation would be valuable preventive measures to apply to every prisoner before he is sent to the camp.

ISOLATION OF THE SICK.

Nearly every camp has some room or small tent which could be used for the isolation of those who are sick. It happens frequently that a prisoner is ailing and unable to work for several days before it is thought necessary to call a doctor. Certain diseases are communicable several days before their true nature is recognizable, and therefore a systematic isolation of all cases of illness might, at times, result in the prevention of a widespread epidemic. A great deal of time lost through epidemics of coughs, colds, and grippe may be avoided if the first cases are properly isolated. Isolation is said to be a powerful weapon against pretended illness and is worthy of consideration from this point of view.

Where the prisoners sleep in close proximity, a distance of 2 feet between the faces certainly is the least that can be demanded and this requires that the sides of the beds shall be at least 2 feet apart.

MEDICAL AND SURGICAL SUPPLIES DESIRABLE FOR A CAMP.

A first-aid outfit and a medicine chest consisting of the following articles should be on hand in every camp:

FIRST-AID REQUIREMENTS.

One 2-ounce bottle of aromatic spirits of ammonia (to be renewed every three months).

One 2-ounce bottle of 4 per cent aqueous boric-acid solution.

One 2-ounce bottle of 3 per cent alcoholic iodine.

Two 3-ounce tubes of 3 per cent bicarbonate of soda in petrolatum.

One 2-ounce bottle of Jamaica ginger.

One 1-ounce jar of green soap (to cleanse hands).

One half-pint bottle grain alcohol.

One 3-inch by 10-yards roll of gauze bandage.

One 2-inch by 10-yards roll of gauze bandage.

Two 1-inch by 10-yards rolls of gauze bandage.

One roll of absorbent cotton (1.5 ounces).

One 4-inch by 5-yards spool of adhesive plaster.

Six yards of 24-inch Canton flannel to make triangular slings.

Six paraffin envelopes, each containing 6 by 36 inch sterilized-gauze dressings for wounds, burns, etc.

Two splints 30 inches by $\frac{3}{16}$ inch, white wood, and one wire-gauze splint about 30 by 4 inches, for fractures. Never put on a splint over a bandage. Put the bandage over the splint, being extremely careful not to make it very tight.

One medicine glass.
One dozen drinking cups (paper), to be used once only.
One eyecup.
One teaspoon.
Two medicine droppers.
One nailbrush.
One 12-inch basin, enameled, or nonrustable material.
One pair 4½-inch scissors.
One pair surgical scissors.
Four 6-inch haemostats.
Two scalpels.
One probe.
One smooth-dressing forceps.
Two soft-rubber catheters, No. 20 F (1 year).
Twelve large safety pins.
Three tubes sterilized catgut sutures, assorted sizes.
One dozen surgical needles, assorted.

MEDICINAL REQUIREMENTS.

Sixteen ounces castor oil.
Sixteen ounces Epsom salts.
One hundred ½-grain tablets calomel and soda.
Five hundred compound cathartic pills.
One hundred 5-grain tablets quinine sulphate.
One hundred 5-grain tablets aspirin.
One hundred 5-grain tablets bismuth subcarbonate.
Eight ounces bicarbonate of soda.
Five hundred tablets Brown's mixture.
Eight ounces potassium iodide solution, 10 grains to the teaspoonful.
Sixteen ounces chloroform liniment.
Eight ounces boric ointment, U. S. P.
Eight ounces sulphur ointment, U. S. P.
Eight ounces mercurial ointment, U. S. P.
One hot-water bag.

How to Check Bleeding.

When an injury to a blood vessel has occurred and a doctor is not within immediate reach, the bleeding must, of course, be controlled. When the bleeding is from an arm or a leg and some distance from the body, a bandage or clean handkerchief should be wrapped around the limb between the place of injury and the body and drawn tight enough to stop the bleeding. The Spanish windlass is made by knotting the handkerchief around the limb loosely, passing a stick through the slack part, and taking up the slack by twisting the stick. To prevent untwisting, the stick then is bound to the limb with one or two other handkerchiefs or bandages. A small, round stone, a cork, or similar object placed in the folds of the handkerchief directly over the blood vessel will assist. Barely sufficient pressure to stop the bleeding should be exerted. The windlass should be loosened every twenty minutes to give the life blood a chance to flow through the part as there is great danger of gangrene (mortification) if the blood is shut off entirely for a longer period.

PERSONAL CLEANLINESS.

When a number of persons are thrown constantly into contact with one another, as they are in camp life, personal cleanliness and good sanitary habits are especially necessary for the preservation of health.

BATHING.

A weekly or semi-weekly bath is insisted upon at practically all camps, and is not infrequently considered by the prisoners the greatest hardship which has to be endured. In a few cases the prisoners are not required to bathe at stated intervals, but are allowed to follow their own inclinations in this respect. This arrangement is unsatisfactory and often results in scuffles among the prisoners, accompanied by more or less ill feeling, because of the forcible bathing by his comrades of some prisoner who has become obnoxious through personal neglect.

Many camps are provided with shower baths, some of which are supplied with hot and cold water. The heating systems are attached to the kitchen range at the smaller camps, and to specially constructed hot-water heaters at some of the larger camps. When such facilities are provided the men are encouraged to bathe daily, but are required to bathe once or twice a week. Certain large camps in the South are equipped with excellent shower-bath systems and require that daily baths be taken by all the convicts. Individual towels and an abundance of soap are furnished. Other camps, while not insisting upon the daily bath, require each man to bathe his feet before going to bed, an excellent rule to be established.

The shower bath is especially well adapted for the use of convict camps. A simple and easily handled apparatus will suffice, and but little water and time are necessary for the bath. The transmission of disease which may occur with the use of a tub is impossible with the shower bath, and the tonic effect of the cold water is of great benefit. The popularity of the shower baths was much greater at those camps where the water was heated, but whenever warm water is used it always should be followed by water as cold as can be borne, and it is well that the men should become accustomed gradually to cold water, at least in the summer. It should be remembered, however, that the shock of a cold bath is severe and that it is dangerous for men who have heart trouble or diseased blood vessels.

At camps where shower baths are not provided, water for bathing purposes is usually heated in large iron kettles suspended over wood fires out of doors. The heated water then is transferred to wooden washtubs or galvanized-iron pails and carried to the nearest place which affords protection. At other camps the water is heated on the kitchen stoves or in metal washtubs placed on open fires.

When tubs or pails are used for bathing purposes it is absolutely necessary that they be scalded out with boiling hot water after every individual bath, in order to avoid the danger of transmitting disease from one person to another.

At one camp a novel method of washing the convicts was in use. Immediately after returning from work the men removed their clothing, formed in line, and the superintendent sprayed them with a hose placed in a tub of water and worked by a hand pump. After the first wetting they were given time to soap themselves, following which the superintendent rinsed them.

Prisoners often are permitted and encouraged to bathe in near-by rivers and ponds in the summer, and this is a privilege which is thoroughly enjoyed. Camp officials should inform themselves as to the condition of the water, however, and men should not be permitted to bathe in dirty water polluted with filth. The best time for bathing is about two hours after a meal. Prisoners should not be permitted to enter the water too soon after eating, when perspiring very much, or when chilled.

Facilities for Washing Face and Hands.

Prisoners at all camps are compelled to wash their faces and hands before meals. Tin washbasins usually are provided, and roughly-constructed washstands are placed at convenient points about the camp. Water for washing purposes is stored near by in barrels or buckets, and soap and individual towels are furnished. At some camps an effort is made to provide individual washbasins, but it is doubtful if this is ever strictly carried out. When cases of syphilis and skin diseases are present in camp, the danger of infection is considerable. Each man should be required to cleanse the basin thoroughly before and after using it.

The washing of the hands after visiting the toilet is one of the most important duties to be performed. It has been absolutely proved that many persons who show no signs of sickness carry the germs of various infectious diseases in their intestinal canals, and the contamination of fingers with those germs is always possible while visiting the toilet, especially by men of unclean habits. Infection then may be carried to the bunk house, mess room, or kitchen. Washing the hands therefore should be insisted upon, and the necessary conveniences should be provided.

Care of the Clothing.

At practically all camps personal clothing is washed either once or twice a week. It is a common custom to detail one or two men to do the laundry work and to give them no other task until the week's wash is completed. As a rule, one or two days are sufficient for this purpose, but at the large camps a longer time is necessary. After being laundered, the clothing is sorted and placed in pigeonholes or on shelves until given out again at the end of the week. Necessary clothing repairs are made by the laundrymen. At a few camps there are no definite rules in regard to washing the clothes, and each man does his own wash in his leisure time. In such cases Sunday morning usually is chosen for laundry work, but there is no assurance that all the men are desirous of keeping their clothing decently clean.

The better camps provide laundry sheds or tents equipped with clothes-washing machines, scrubbing boards, wringers, and other paraphernalia. Water is heated in iron heaters made especially for the purpose and consisting of a firebox and large iron caldron. Boiling water is drawn from the heaters into metal tubs, in which the clothes are washed with soap. Lines are strung in the sun for the purpose of drying the clothes. In other cases the laundry rooms are provided with cookstoves, on which water is heated in wash boilers or metal tubs.

At one camp a ditch was dug from a rapidly-flowing mountain stream to the laundry tent, and then led back to the stream at a point lower down. By this means a plentiful supply of running water was obtained easily.

At some camps a large iron kettle is suspended over a fire out of doors for heating the water for laundry and bathing purposes, or metal washtubs may be placed directly over the open fires and the clothing boiled out in that way. In such cases the laundry work is all done out of doors, without overhead protection.

In the process of laundering, the clothing should first be soaked in cold or tepid water. This removes a certain amount of the dirt and filth which would not come out so easily if heated first, and the water becomes laden with germs from the skin and body which may be very dangerous. It is important, therefore, that this water should be disposed of in such a way that it will not pollute the soil or the water supply of the camp.[1] After the preliminary soaking the clothing should be boiled with soap, and then rinsed in pure water until clean. Boiling destroys any germs which may be in the clothing, but it does not remove the bad-smelling substances absorbed from the skin. Rinsing in a sufficient amount of pure water (preferably running water) will accomplish this and at the same time remove the soap, which might prove irritating to the skin if allowed to remain. Properly laundered clothing should have no other than a clean, sweet smell.

Convicts entering a camp from the jails are sometimes in a filthy condition and loaded with vermin. In order to guard against the introduction of disease germs and vermin, every new man who is sent to a camp should be bathed and provided with clean clothing before being allowed to enter the quarters, and his old clothing should be thrown immediately into boiling water and thoroughly washed out.

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[1] See Disposal of Wastes, p. 104.

Night Clothes and Bedding.

Night clothes are furnished at a few camps, and these, with rare exceptions, are in the South. At a great majority of the convict camps the prisoners remove their outer clothing consisting of shirt, pants, shoes, and socks and sleep in their underclothes which they have worn while at work during the day. This clothing, wet with perspiration and soiled with the excretions of the skin, often remains in contact with the body for a week at a time, a condition not conducive to cleanliness or health.

Sheets are furnished at some of the southern camps, but are seldom found elsewhere. Thus the underclothing worn at hard manual labor throughout the day comes into direct contact with the blankets. In many camps the blankets never are washed, even when a change of ownership occurs. They become indescribably filthy and constitute a very dangerous means by which infectious matter may be conveyed from one man to another.

Mattresses stuffed with cotton, moss, hay, or straw are in common use and seldom receive attention until they are worn out. At certain camps, however, mattress covers are washed and refilled with fresh hay or straw at intervals varying from one to six months.

Pillows filled with hen feathers or moss are almost always furnished, and are provided with slips which are washed each week.

At some camps all bedding is hung out of doors in the sunlight for several hours one day each week and may also be beaten, but at other camps the care of the bedding is left to the men themselves, with the result that it receives no attention at all.

PROPER CARE OF NIGHT CLOTHES AND BEDDING.

No camp can be considered as showing proper regard for the principles of cleanliness and health unless nightshirts and sheets are provided and their use is insisted upon. They should be washed once a week. A certain number of the southern camps have put this plan into operation, and are well satisfied with the results.

All bedding should be taken out of doors and shaken, sunned, and aired for several hours once or twice a week. The purifying action of the sun is of great value in keeping bedding in good condition. Blankets may be prevented from becoming foul by the use of sheets, but should be laundered at least twice a year, and whenever a change of ownership occurs. Every man who enters a camp should be given fresh, clean blankets.

Iron bunks are much better than wooden bunks. They can be kept free from vermin easily, and are more comfortable and durable. When bunks with straw bedding are used, the straw or hay should be changed at least once a week.

QUARTERS AND STRUCTURES.

The quarters and structures in use in convict camps in the United States are of the following types: (1) Frame structures built for relatively permanent occupation; (2) cheap shacks with tar-paper roofing or covered on all sides with tar paper; (3) structures with galvanized metal roofs and canvas sides; (4) shacks with wooden sides and canvas roofs; (5) abandoned cabins or farm houses; (6) buildings of the portable or "knock-down" variety; (7) canvas tents; (8) wooden or steel cars or cages mounted on wheels.

Each of these types may serve to good purpose when used in connection with the conditions to which they are fitted and when represented by structures of good design; but, as frequently happens, they also may be used inappropriately in an environment to which they do not belong, and in such cases, even though the structures themselves are of good design, their use may result in inadequacy or lack of economy.

In any case, the choice of type will be influenced by a number of conditions, such as the following:

(*a*) The normal range of temperature of the locality. Thus, though the generally warm or mild temperatures of the extreme southern sections of the country will permit of the use of tents or even of shelters with open sides, the cold winters of the Northern States demand tightly constructed buildings.

(*b*) The rainfall and humidity of the section. In a section of heavy precipitation, such as the coastal regions of the States of Oregon and Washington, only buildings of the closed-in, tightly constructed types should be used, and these should be raised above the ground in order to escape the evil effects of the excessive moisture. Canvas tents would be out of place under such conditions not only because of the small protection they afford but because they would deteriorate very rapidly in such a climate. On the other hand, in the arid and semiarid sections of Arizona, New Mexico, and neighboring States tents make ideal quarters. Not only do they provide sufficient protection against weather but in the absence of moisture and heavy winds they give excellent service for relatively long periods.

(*c*) The availability of building material. The inducement to use wood in the construction of quarters in those sections of the country which are heavily wooded, and where wood is accordingly cheap, may be sufficient to outweigh a number of other important considerations; but in the Central and Middle Western States the use of wooden quarters probably would be avoided, at least for temporary camps, on account of the scarcity of wood.

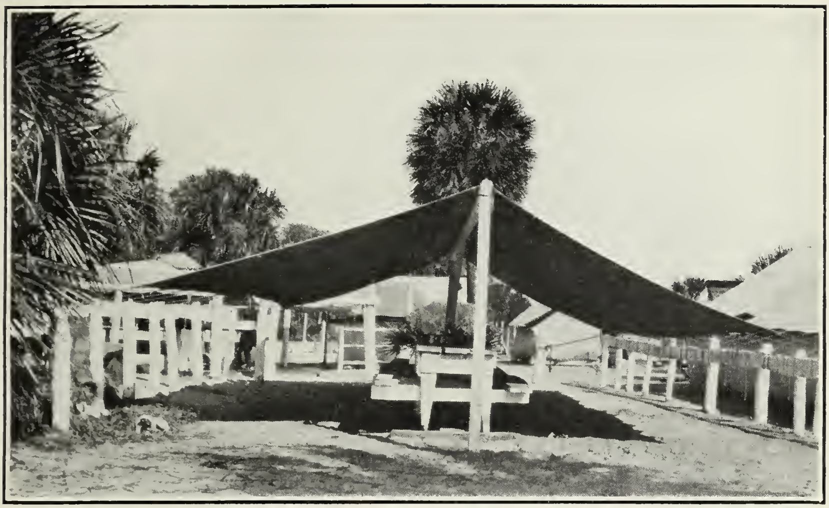
(*d*) The relative permanence of the camp on one site. A camp which reasonably may be expected to remain in one place for four or five years or longer may be treated as a permanent establishment and a type of construction may and should be adopted which, for more temporary quarters, would be too wasteful. Obviously, tents are suitable only for what are termed "flying camps" and would be out of place in a permanent camp.

(*e*) As between the various types suitable to the purposes of a temporary camp, the choice of a particular type will be affected by a consideration of the frequency of the moves, the probable distances between successive camp sites, and the character of the roads over which it will be necessary to move the camp equipment. When moves are to be frequent, distances great, and roads bad, the lightness of tent equipment might be expected to outweigh many other considerations. Under more favorable road conditions considerations of economy might recommend the use of cars or cages, though the use of such equipment is to be avoided whenever possible on account of the extremely unpleasant associations attending their use. Finally, for camps of a somewhat less mobile character well-designed portable houses of metal or wood will serve admirably.

(*f*) Lastly, an important consideration is the character of the inmates to be housed, with respect to their relative trustworthiness, race, crimes, and sentences, it being obvious that a more secure type of building is necessary for the confinement of the desperate and unreconciled than for "honor" men and "trusties."

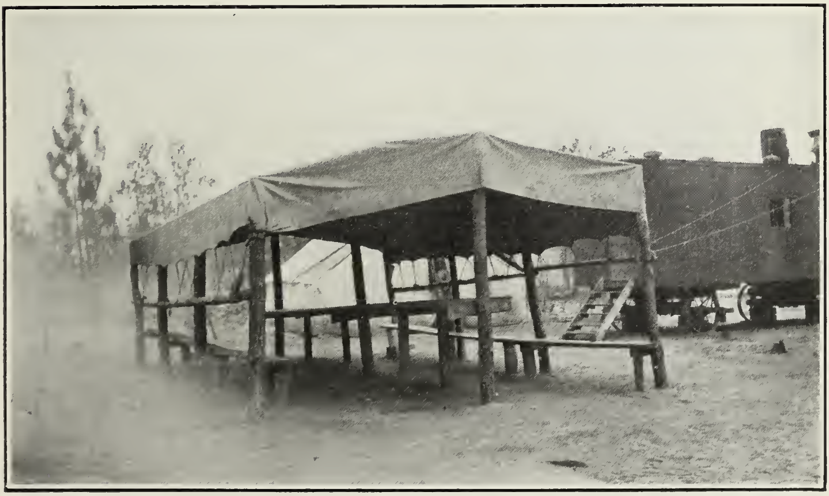
After the most convenient type of building has been selected in view of the foregoing considerations, attention should be given to see that the structures selected or designed embody certain essential properties which should be common to buildings of all types.

First of these is economy. But giving this property the first consideration does not mean that it should be achieved at the expense of all the other properties essential to a good structure, but, rather, that it should be considered in providing for the other properties, all of which may be attained in either an extravagant or an economical manner. In general, it may be stated that the interests of true economy are best served by those forms of structures which embody all the properties essential to their purpose, including longest service for least cost, which is obviously not equivalent to mere cheapness of first cost. For example, a well-designed portable building would undoubtedly be found more economical for a temporary camp than many of the cheap shacks which are used for that purpose, for, though the latter are less expensive at first, their frequent tearing down and rebuilding, accompanied by a necessary loss of material, make them



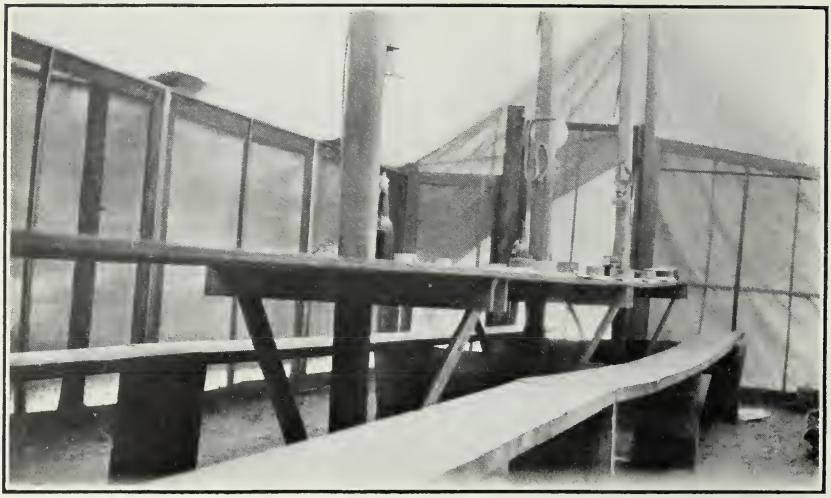
OPRRE12098

FIG. 1.—NEAT AND ATTRACTIVE MESS SHELTER.



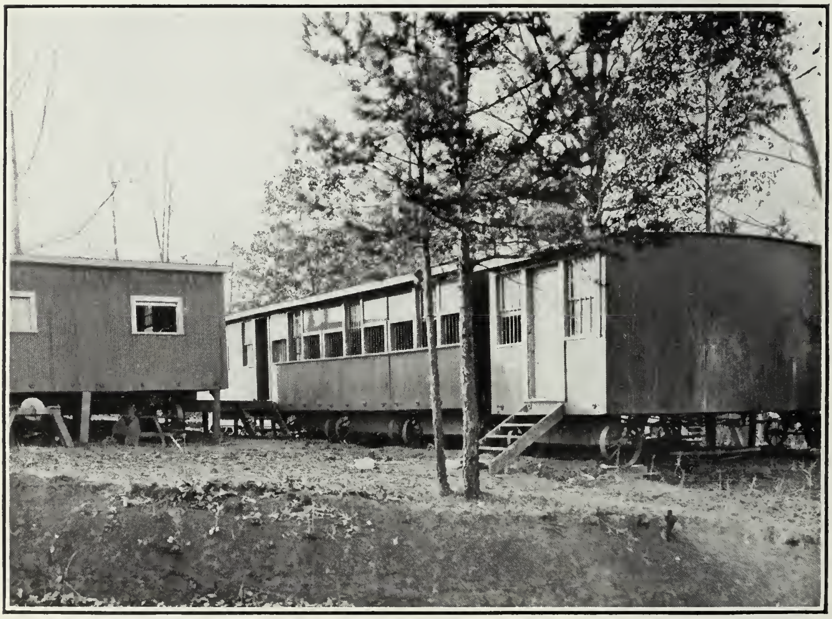
OPRRE12112

FIG. 2.—POORLY ARRANGED AND UNINVITING MESS SHELTER.



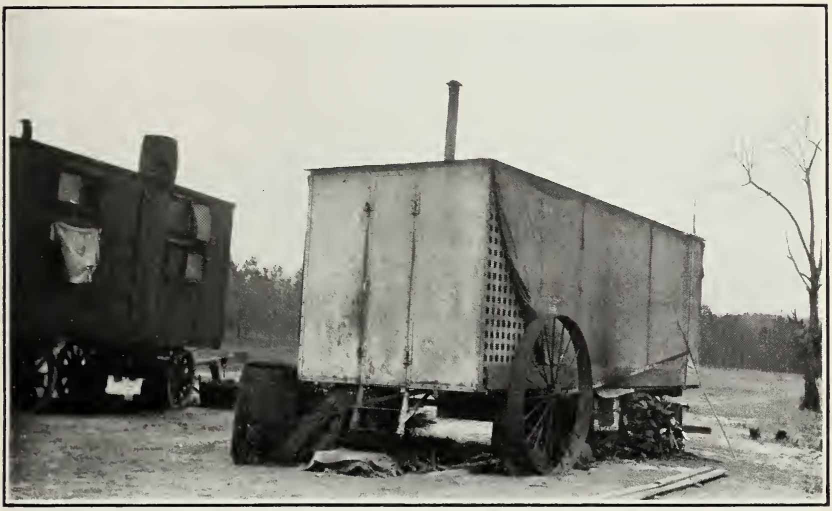
OPRRE12063

FIG. 1.—SCREENED MESS TENT.



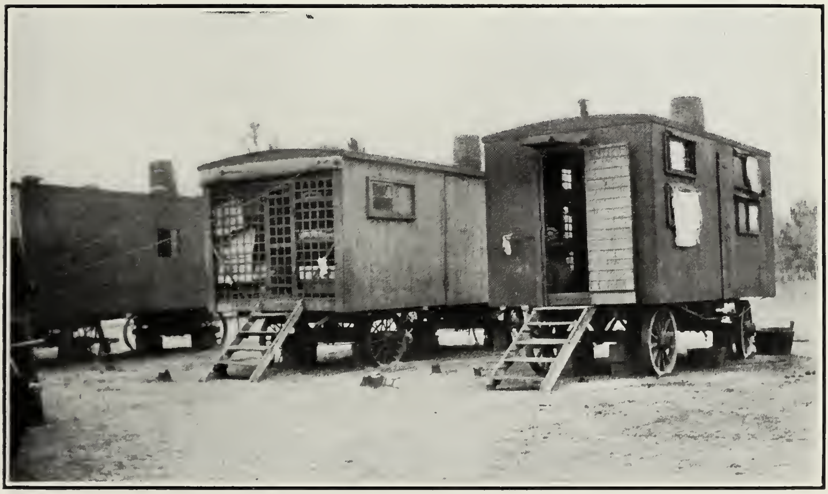
OPRRE2347

FIG. 2.—CONVICT CARS JOINED TO MAKE ONE BUILDING.



OPRRE12110

FIG. 1.—TYPE OF ALL-STEEL CAGE.



OPRRE12113

FIG. 2.—TYPE OF WOODEN CAGES.

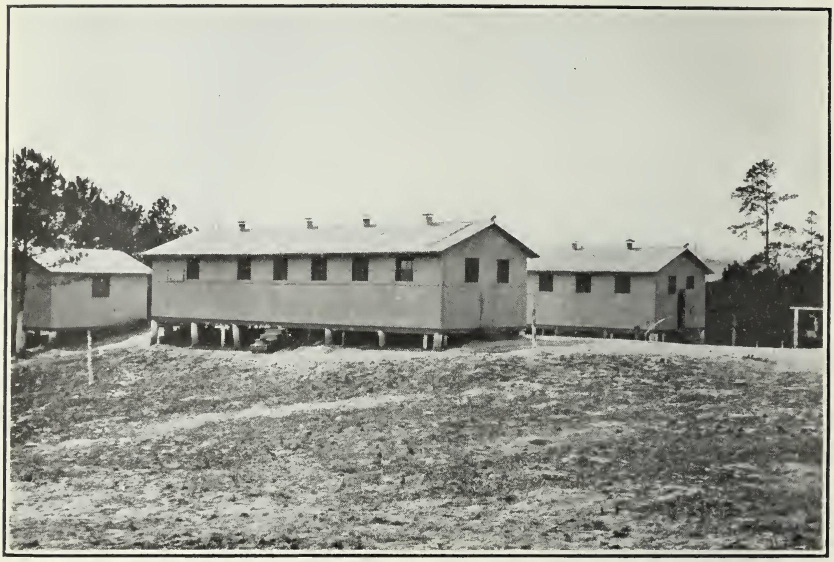
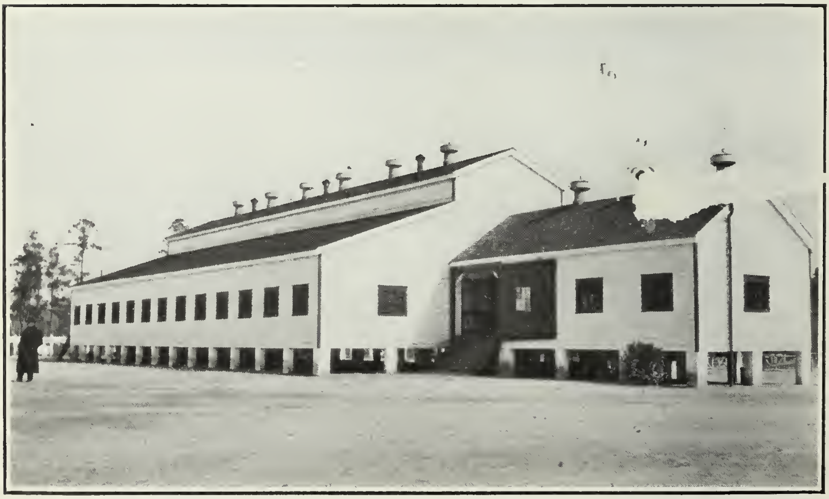


FIG. 2.—PORTABLE BUILDINGS.



OPRRE12126

FIG. 2.—PERMANENT FRAME QUARTERS OF GOOD DESIGN.

more costly in the long run. In fact, it is often found less costly to abandon these shacks completely.

Bearing in mind, then, what has been said about economy, the second essential property of a good camp structure is that it shall present a neat and well-kept appearance and that the peculiar nature of its use as a place of confinement for criminals should not be obtrusively apparent. As illustrative of the effect of this attention to appearance, it will be well for the reader to compare the views of the two mess shelters shown on Plate VII. In all structural essentials the two shelters are exactly similar, both consisting of a simple center table with continuous benches on each side, the whole covered by a canvas "fly" or roof. The more pleasing appearance of the one is attained at the expense of a single coat of whitewash, the cheapest of paints.

The third essential property of all structures is that they should be so planned as best to serve the convenience of their occupants. Thus, in the first of the two photographs discussed in connection with the preceding paragraph it will appear that the benches along each side are attached to the side posts, being separated from the table by a distance of several feet, a most inconvenient arrangement which prevents the proper use of the table. How readily this condition might have been improved at no greater cost is demonstrated by the second photograph. This is typical of the numerous simple expedients which may be adopted to promote the convenience of quarters of all sorts. Others, such as the proper placing of toilets and baths with reference to sleeping quarters, of the commissary or storeroom with reference to the kitchen and dining room, the provision for hanging clothing in the sleeping quarters, need only to be mentioned to be appreciated.

As a fourth common property, all camp structures should be planned with reasonable consideration for the physical comfort of the inmates. Structures designed for use in warm climates should be so arranged that they may be thrown open to admit an abundance of fresh outside air, and, on the other hand, buildings to be used during extremely cold weather should have double-sheeted walls and double floors so that they may be adequately heated.

That their arrangement should prevent, as far as possible, the accumulation of filth, and should permit easy cleaning is another property which structures of all types should have in common. Re-entrant angles, cracks, crevices, holes, and other places of lodgment for dust and vermin should be avoided, and when this is not possible they should be made readily accessible for the purpose of cleaning. Furthermore, it is a good plan to paint all interior wooden surfaces in such way as to proclaim rather than conceal the presence of dirt.

Proper observance of the rules of ventilation and screening, given elsewhere, should be another common property of all structures for camp use. Attention to these features is a great aid toward assuring the health of the inmates.

A measure of security commensurate with the requirements of the particular grades of convicts which they are designed to house should also be provided by all convict-camp structures. Buildings designed for the quartering of "honor convicts" may be relatively insecure, but the lower or more desperate characters must be held by the various means of bars and locks, chains and stockades.

Finally, it is frequently desirable, in camps of variable population, to design the structures so as to allow ready reductions or increases in capacity.

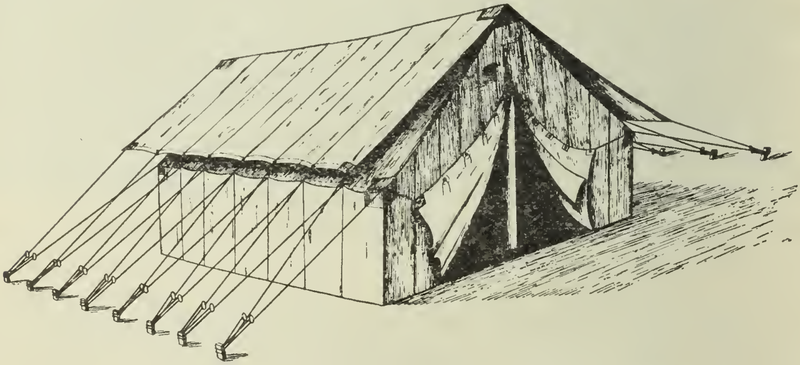


FIG. 7.—Wall tent.

The foregoing are the principal properties which should be realized in all types of camp buildings. In order to indicate how these properties may be embodied in such structures, the various types are hereafter discussed in detail, with plans, specifications, costs, and other available data given for a number of structures.

TENTS.

The form of tent used most extensively in connection with convict camps in the United States is the "wall tent" shown in figure 7. Such tents are supplied by the trade in various weights of cotton duck, designated according to the weight per yard, as 6½, 8, 10, and 12 ounce duck, the last-named weight being the heaviest goods in common use. Lightweight twills, measuring 30 inches in breadth and weighing from 6½ to 8 ounces per yard, are the materials usually employed in the construction of the largest sized tops, while 8, 10, and 12 ounce ducks are used in the smaller sizes.

The door openings usually consist of flaps placed in the ends of the tent, though special side-opening tents also are obtainable. The ventilator and stovepipe opening is another very desirable one, always provided in Government tents. This opening usually is placed directly below the ridge at the left of the entrance. It measures 6 inches in breath and 8 inches in length, and is covered by a lapel secured on the inner side.

Tents may be screened effectively by hangings of five-mesh English bobbinet around the sides and over all openings, or by means of galvanized-wire screen sections inserted as indicated in Plate VIII, figure 1.

For winter use tents should be floored at least 12 inches above the ground.

Tables 14 and 15 show the common sizes of wall tents, their dimensions and approximate costs when made of the various grades of material, and also the maximum permissible number of occupants for each size. The prices given are list prices for 1915, include poles and stakes, and are subject to a discount of from 35 to 50 per cent.

Table 16 shows the dimensions of a number of sizes of stable tents and gives the prices of each of the sizes made of the various grades of duck. The prices are approximate list prices of 1915, and are subject to from 35 to 50 per cent discount, but they are for complete tents, including tops, sides, and all necessary poles and stakes. For the top, poles, and stakes, but without sides the list prices run from 65 to 75 per cent of those given in the table.

TABLE 14.—*Wall tents, not roped.*

Size.	Height of ridge.	Height of wall.	List prices as of 1915, subject to from 35 to 50 per cent discount.						Maximum number of occupants permitted.
			8-ounce duck, single filling.	10-ounce duck, single filling.	10-ounce duck, double filling.	12-ounce duck, double filling.	12-ounce army duck or No. 10.	15-ounce army duck or No. 8.	
Feet.	*Feet.*	*Feet.*							
7 by 7	7	3	$8.00	$9.35	$10.35	$12.25	$14.55	$17.50	1
7 by 9	7	3	9.50	11.05	12.30	14.60	17.40	20.90	2
8 by 8	7	3	9.36	10.91	12.13	14.37	17.12	20.57	2
9 by 9	7½	3	10.95	12.80	14.30	17.00	20.30	24.50	2
9½ by 12	7½	3	12.90	15.05	16.80	19.95	23.80	28.70	4
9½ by 14	7½	3	14.65	17.10	19.10	22.65	27.05	32.55	4
12 by 12	8	3½	15.30	17.95	20.00	23.75	28.40	34.25	4
12 by 14	8	3½	17.30	20.20	22.55	26.80	32.05	38.60	6
12 by 16	8	3½	19.20	22.45	25.05	29.80	35.65	43.00	6
12 by 18	8	3½	21.35	24.95	27.80	33.00	39.45	47.50	8
14 by 14	9	4	20.60	24.15	26.95	32.10	38.45	46.45	6
14 by 16	9	4	22.70	26.65	29.80	35.50	42.55	51.35	8
14 by 18	9	4	25.35	29.75	33.20	39.45	47.30	57.10	10
14 by 20	9	4	28.20	32.75	36.40	43.00	51.15	61.40	10
14 by 24	9	4	31.80	36.90	41.00	48.10	57.25	68.75	12
16 by 16	10	5	28.20	33.20	37.15	44.10	53.05	64.25	10
16 by 18	10	5	30.95	36.40	40.75	48.25	58.00	70.20	12
16 by 20	10	5	34.10	39.80	44.30	52.15	62.30	75.00	14
16 by 24	10	5	38.85	45.20	50.25	59.05	70.40	84.65	16
16 by 30	10	5	47.00	54.75	60.85	71.50	85.30	102.60	22
16 by 35	10	5	52.60	61.30	68.10	80.20	95.60	114.95	26
18 by 18	11	5	35.40	41.60	46.45	55.20	66.20	79.95	14
18 by 20	11	5	39.00	45.45	50.50	59.70	71.10	85.45	14
18 by 24	11	5	43.60	50.85	56.50	66.50	79.25	95.25	18
18 by 30	11	5	52.25	60.90	67.75	79.95	95.35	114.65	22
18 by 35	11	5	58.15	67.80	75.40	89.05	106.25	127.75	26

TABLE 15.—*Wall tents, roped.*

Size.	Height of ridge.	Height of wall.	List prices as of 1915, subject to from 35 to 50 per cent discount.						Maximum number of occupants permitted.
			8-ounce duck, single filling.	10-ounce duck, single filling.	10-ounce duck, double filling.	12-ounce duck, double filling.	12-ounce army duck or No. 10.	15-ounce army duck or No. 8.	
Feet.	*Feet.*	*Feet.*							
21 by 30	12	5	$89.00	$101.00	$113.00	$127.50	$141.50	$173.50	24
21 by 35	12	5	104.50	118.50	132.50	149.50	166.00	204.00	28
21 by 40	12	5	115.00	130.50	146.00	164.50	182.50	224.50	36
21 by 49	12	5	136.00	154.50	173.00	194.50	216.50	265.50	44
24 by 28	13	6	105.50	120.00	134.50	151.00	168.00	206.50	28
24 by 35	13	6	125.00	142.00	159.00	179.00	199.00	244.00	38
24 by 42	13	6	144.50	164.00	183.50	206.50	229.50	282.00	48
24 by 51	13	6	169.50	192.50	215.50	242.50	269.50	331.00	58
24 by 60	13	6	195.00	221.50	248.00	279.00	310.00	381.00	68
24 by 65	13	6	207.50	236.00	264.50	297.50	330.50	406.00	70
30 by 37	15	6	160.00	182.00	204.00	229.50	255.00	313.00	48
30 by 42	15	6	175.00	199.00	223.00	250.50	278.50	342.50	58
30 by 47	15	6	189.50	215.50	241.50	271.50	301.50	370.50	60
30 by 51	15	6	204.00	232.00	260.00	292.50	325.00	399.00	70
30 by 56	15	6	219.00	249.00	279.00	313.50	348.50	428.50	72
30 by 60	15	6	233.50	265.50	297.50	334.50	371.50	456.50	82
30 by 65	15	6	248.50	282.50	316.50	356.00	395.50	486.00	84
30 by 70	15	6	263.00	299.00	335.00	376.50	418.50	514.50	94

TABLE NO. 16.—*Stable tents.*

Size.	Height of wall.	Height of pole.	10-ounce double filling or 8-ounce army duck.	12-ounce double filling or 10-ounce army duck.	12-ounce army or No. 10 duck.	15-ounce army or No. 8 duck.
Feet.	*Feet.*	*Feet.*				
24 by 21	5	12	$104.00	$117.00	$130.00	$160.00
24 by 33	5	12	142.00	160.00	178.00	218.50
24 by 42	5	12	173.00	194.50	216.50	265.50
24 by 60	5	12	234.50	264.00	293.50	360.50
24 by 72	5	12	273.00	307.50	341.50	419.50
26 by 21	5	12½	111.50	125.50	139.50	171.00
26 by 33	5	12½	152.00	170.50	189.50	233.00
26 by 42	5	12½	184.00	207.50	230.50	283.00
26 by 51	5	12½	216.00	243.00	270.00	332.00
26 by 60	5	12½	248.50	279.50	311.00	382.00
26 by 72	5	12½	289.00	325.00	361.00	444.00
26 by 82	5	12½	321.00	361.00	401.00	493.00
26 by 91	5	12½	333.50	397.50	441.50	542.50
28 by 24	5	13	128.25	144.25	160.25	197.00
28 by 35	5	13	170.75	192.25	213.50	262.25
28 by 42	5	13	196.50	221.25	245.75	302.00
28 by 51	5	13	230.25	259.00	287.75	353.50
28 by 60	5	13	265.00	298.00	331.00	406.75
28 by 72	5	13	307.50	346.00	384.50	472.00
28 by 84	5	13	353.00	397.00	441.00	542.00
28 by 100	5	13	416.50	469.00	521.00	640.00
30 by 24	5	14	139.00	156.00	173.50	213.50
30 by 35	5	14	184.00	207.50	230.50	283.00
30 by 42	5	14	211.00	237.50	264.00	324.00
30 by 60	5	14	283.50	319.00	354.00	435.00
30 by 72	5	14	328.00	369.00	410.00	504.00
30 by 84	5	14	373.00	419.50	466.00	573.00
30 by 100	5	14	445.00	501.00	556.50	683.50

The following are the United States Army specifications for duck adopted April 27, 1915:

KHAKI, 12.4-OUNCE.

Material.—The yarn to be made of American cotton. The fabric woven in a workmanlike manner and free from imperfections. To be thoroughly brushed to remove motes or other foreign substances.

Threads.—To contain not less than 46 threads of 3-ply yarn to the inch of warp, and not less than 32 threads of 4-ply yarn to the inch of filling.

Strength.—To sustain a tensile strength of not less than 116 pounds to the one-half inch in the warp and not less than 90 pounds to the one-half inch of filling.

Width.—To be full 29½ inches wide when finished, with a blue thread of 3-ply yarn woven in the fabric 1 inch from each selvage.

Weight.—To weigh not less than 12.4 ounces nor more than 13 ounces to the linear yard.

Color.—To be a khaki shade as represented by the sealed standard sample and may be dyed in the raw stock, yarn, or piece. Bleaching, half bleaching, or scouring before dyeing is not permitted. To be evenly and regularly dyed and to be subjected to the following official tests for ascertaining permancy of color:

1. Boiling for 10 minutes in a solution of soap (80 grains of olein soap, army issue, to 1 pint of water).
2. Boiling 10 minutes in a solution of soda (10 grains of bicarbonate of soda to 1 pint of water).
3. Whenever deemed necessary by the contracting officer the duck will be subjected to exposure to sunlight, air, and moisture for a period of 30 days.

KHAKI, 8-OUNCE.

Material.—The yarn to be made of American cotton. The fabric woven in a workmanlike manner, free from imperfections. To be thoroughly brushed to remove motes or other foreign substances.

Threads.—To contain not less than 54 threads of 2-ply yarn to the inch of warp, and not less than 34 threads of 2-ply yarn to the inch of filling.

Strength.—To sustain a tensile strength of not less than 75 pounds to the one-half inch in the warp and not less than 50 pounds to the one-half inch in the filling.

Width.—To be full 28½ inches wide when finished, with a blue thread of 3-ply yarn woven in the fabric 1 inch from each selvage.

Weight.—To weigh not less than 8 ounces nor more than 8½ ounces to the linear yard.

Color.—To be a khaki shade as represented by the sealed standard sample and may be dyed in the raw stock, yarn, or piece. Bleaching, half bleaching, or scouring before dyeing is not permitted. To be evenly and regularly dyed and to be subjected to the following official tests for ascertaining permanency of color:

1. Boiling for 10 minutes in a solution of soap (80 grains of olein soap, army issue, to 1 pint of water.
2. Boiling 10 minutes in a solution of soda (10 grains of bicarbonate of soda to 1 pint of water).
3. Whenever deemed necessary by the contracting officer, the duck will be subjected to exposure to sunlight, air, and moisture for a period of 30 days.

The life of tents depends so greatly upon climatic conditions that no general estimate can be made here. Experience indicates that the period of satisfactory service will vary from six months to three years. In humid regions and in sections of prevailing high winds little more than the lower limit of usefulness can be expected; but in relatively dry climates and where high winds are infrequent the life of canvas may be even greater than the three-year period mentioned. Tents which are improperly cared for frequently deteriorate rapidly from mildew. This usually is the result of rolling and storing the canvas while wet, and the best means of preventing it is to dry the tentage thoroughly before storing. A number of processes have been devised for mildew-proofing, but none has given entire satisfaction. The process in most general use consists of immersing the duck for a suitable period in a solution of alum and sugar of lead, the proportions being 4 pounds of each ingredient to one barrel of water. Other recipes for this purpose follow:

1. Dissolve 1 pound of zinc sulphate in 40 gallons of water; add 1 pound of washing soda, and when this is dissolved add 2 ounces of tartaric acid. Soak the material 24 hours and allow it to dry without wringing.

2. Dissolve 2 pounds of alum in 7 gallons of hot water. Dissolve 1 pound of gelatin in 4 gallons of hot water. Mix these two solutions, then dissolve 2 pounds of blue vitriol in 1 gallon of hot water and add the solution to the mixture of the first two. Soak the duck in the resulting mixture 24 hours and allow to dry without wringing.

CAGES AND CARS.

Movable convict quarters mounted on wheels, known as cages (or lately, in response to a change in public feeling, as cars), have long been in common use in the United States, particularly in the South.

Formerly constructed entirely of wood, they now are also manufactured wholly of steel by a number of firms. In dimensions they are usually 12 or 18 feet in net length and from 7 to 8 feet in width and height.

The cost of a steel cage 18 by 8 by 8 feet is approximately $500, which is at the rate of 43.4 cents per cubic foot of space provided. By way of comparison, it may be stated that an excellent portable building, similar to that described in a succeeding paragraph, can be constructed at a cost of not more than 7 cents per cubic foot of space provided below the eaves, entirely omitting from consideration the additional space between the eaves and the ridge. Such a structure should have a life of at least five years. If, therefore, omitting for the present the consideration of the relative portability of the two types of quarters, the cage is to equal the portable building in economy, it must have a life approximately six times as long, or at least 30 years. It is not known precisely what life may be expected of the cage, for the reason that steel cages have not been in use long enough to provide any basis for an estimate; but it is not probable that its life will equal the 30-year period which is necessary to place it on an economic parity with the portable building.

From the standpoint of mobility the cage usually is regarded as somewhat superior to the portable building, because in transporting the latter there is involved the tearing down and reerecting processes in addition to the actual transportation of the buildings, whereas the cage mounted on wheels has only to be hauled from one location to another and is always ready for occupancy. However, this advantage never is fully realized, owing to the fact that the great weight of the cage, from 3 to 4 tons, makes it extremely difficult to transport over bad roads. In one county in Alabama it required two days for eight teams of mules to move a steel cage 12 miles over the muddy roads. Though this is, perhaps, an extreme example, the same objection applies in lesser degree under better conditions.

Furthermore, the time in moving saved by the use of cages is unimportant except in those cases where the camp is moved very frequently, which frequent moving implies the performance of very light road work shown elsewhere to be generally uneconomical with convicts. When the camp is maintained in one location for from four to six months or longer, as is desirable, the interest and depreciation on the running gear usually will be found practically to absorb the value of the time saved in moving.

Thus, from the standpoint of economy alone, apart from the sanitary and sentimental objections, the cage is found to be unsatisfactory.

The illustrations in Plate IX, figures 1 and 2, show types of wooden cars and steel cages, and Plate VIII, figure 2, represents a somewhat less objectionable type of wooden car. The latter is so arranged that by removing the adjacent sides two or more cars can be joined to form a single building as shown.

PORTABLE BUILDINGS.

For the purposes of temporary camps, probably the best type of housing is the portable building. This type has been adopted in many places with excellent success, and no doubt it will be brought into wider use when its merits are more widely recognized. Properly designed and constructed, buildings of this type have much the same advantages as tents in point of mobility, and they have the further merits of furnishing greater protection from weather and greater security and longer life than tents; also, they furnish sufficient security at lower cost and with less objectionable appearance than cars or cages.

They may be constructed of wood or metal or of a combination of the two materials. Those made entirely of metal have the advantage of long life and of being fireproof and relatively vermin proof, but they are much more expensive than wooden structures, somewhat heavier, inconvenient to replace in case of breakage and deterioration, hot in summer and cold in winter. When made principally of wood they are less expensive, much cooler in summer, lighter and easier to move and handle, but subject to damage or destruction by fire, more difficult to keep clean and free from vermin, and with shorter lives than metal buildings.

Whatever material be used in the construction, the following desirable features should be embodied in the design:

(1) The sections of which the building is composed should be of such size as to permit convenient hauling and erecting. They should not be too large for transportation on an ordinary wagon bed, and in weight they should not exceed approximately 200 pounds, the maximum weight which can be handled successfully by two men in erecting and tearing down.

(2) The sections should be so designed and the connections so made as to secure the maximum of flexibility in the building and permit ready reduction or increase in capacity to accommodate any number of inmates.

(3) All parts and sections should be constructed by template or pattern, in order that similar parts may be absolutely interchangeable.

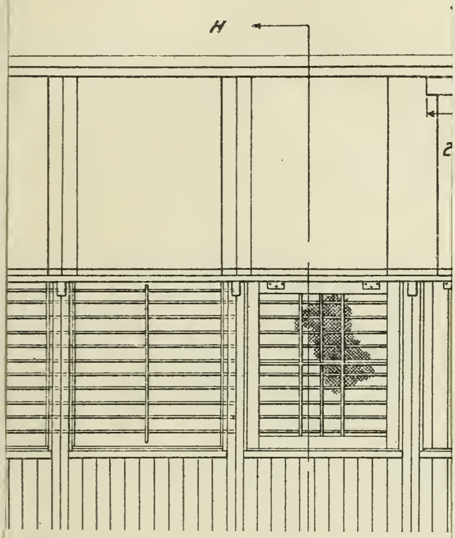
(4) All units should be so simple in design that they may be constructed by relatively inexperienced labor. Complicated joints, irregular shapes, and difficult cuts should be avoided.

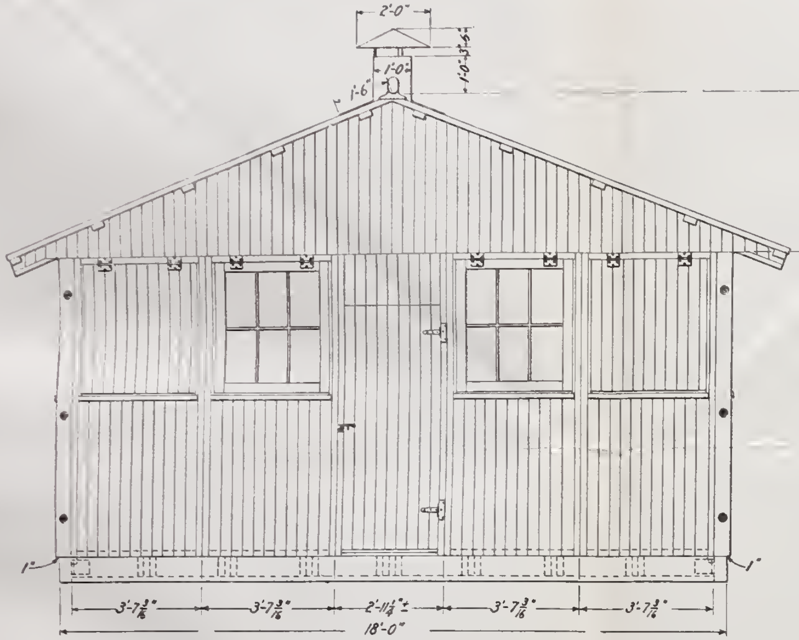
(5) All the parts should be so-called stock articles or easy to improvise, in order that the cost may be reduced to a minimum and that renewals may be made with the greatest ease.

Stock buildings of either metal or wood, embodying the above desirable features, may be purchased from a number of manufacturers in various parts of the United States, or they may be very readily constructed by the regular convict force under the leadership and supervision of a good carpenter. The latter means probably will appeal more strongly to prison officials, as the convict labor usually is available for the work, and by employing it the buildings can be constructed at a lower cost than they can be bought.

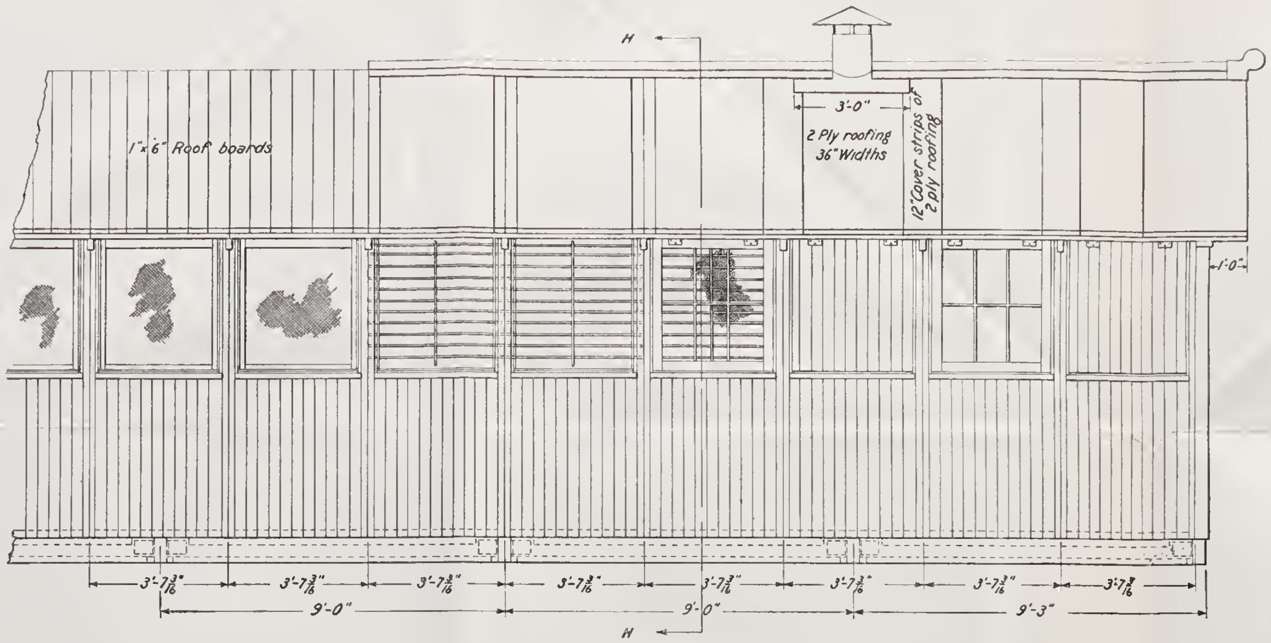
For the assistance of communities in which it is desired to erect buildings of this character, the Office of Public Roads and Rural Engineering is prepared to furnish upon application complete detailed plans and specifications of the portable building shown in Plate X, figure 1, the general plans of which are given in Plate XI.

In the preparation of these plans careful attention has been given to all the featurres mentioned above as desirable. The sections are designed for rapid erection of buildings 18 feet square, or, by pro-

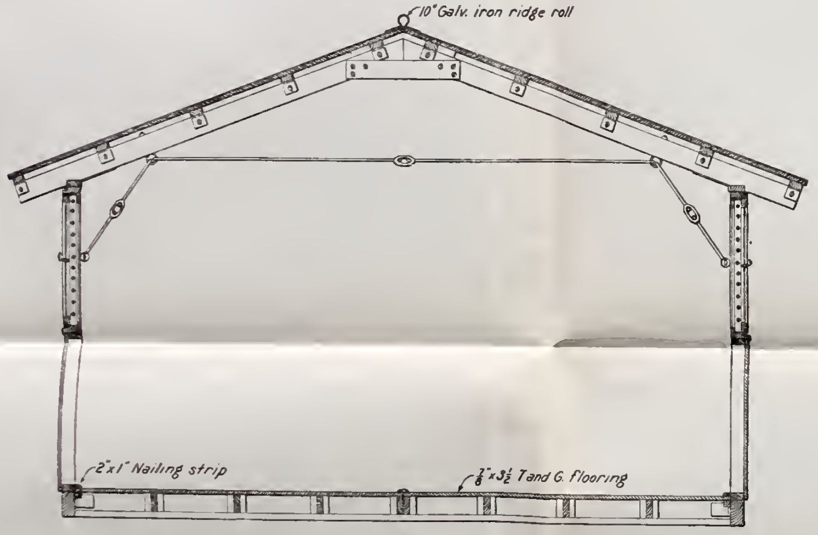

H
2



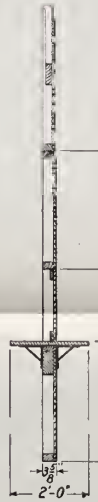
END VIEW



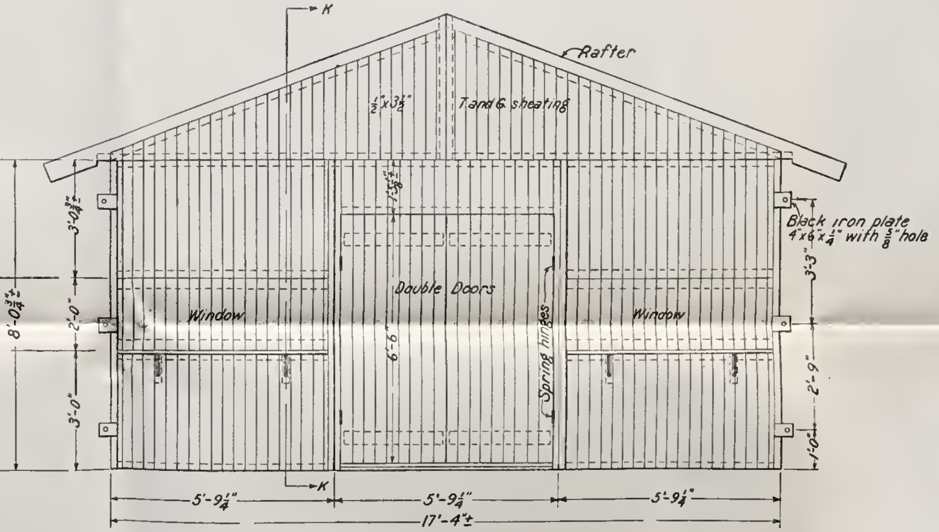
SIDE VIEW



SECTION H-H



SECTION K-K



KITCHEN-DINING ROOM PARTITION

U.S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

GENERAL VIEWS

PORTABLE CONVICT CAMP BUILDING

SCALE, ½" = 1'-0"

CORRECT H. S. Fairbank HIGHWAY ENGINEER

APPROVED J. E. Pennybacker CHIEF ROAD ECONOMICS

E-57

DESIGNED BY H. S. Fairbank DATE 2-15-16
TRACED BY D. P. Golem DATE 3-21-16
CHECKED BY H. S. Fairbank DATE 3-24-16

vision for the joining of several buildings, into buildings 18 by 36 feet, 18 by 54 feet, or larger. They are adaptable for either guarded or honor camps and for all the purposes of such camps, as for convicts' sleeping quarters, mess halls, kitchens, storehouses, lavatories, and baths, and for guards' and superintendents' quarters, or office buildings. As sleeping quarters each 18 by 18 foot building will accommodate a maximum of 16 persons, by the use of double-decked metal cots arranged along each side of the building with their length perpendicular to the walls, which arrangement provides for an aisle of 4½ feet down the center. With this maximum number of inmates, the building provides approximately 20 square feet of floor space and 200 cubic feet of air space per inmate, which allowance, in view of the excellent means of ventilation provided, is entirely adequate. Window spaces, 42 inches deep, closed by solid wooden shutters and glazed sashes, extend the full length of all sides of the building, with the exception of the space necessary for doors, and by opening these windows in summer it is possible to keep the air inside the buildings down to the temperature of the outer air. The shutters and windows are hinged at the top and swing outward, and when they are open they act as awnings for protection from the weather. All doors and windows are provided with 16-mesh galvanized-wire screens. Security can be provided in guarded camps by barring the windows, by chaining the prisoners to their bunks, and by the insertion of a cage vestibule inside one of the doors of the sleeping quarters as a station for the armed night guard. Such a cage may be constructed of No. 5 steel-wire screening with a 2-inch mesh (fig. 8).

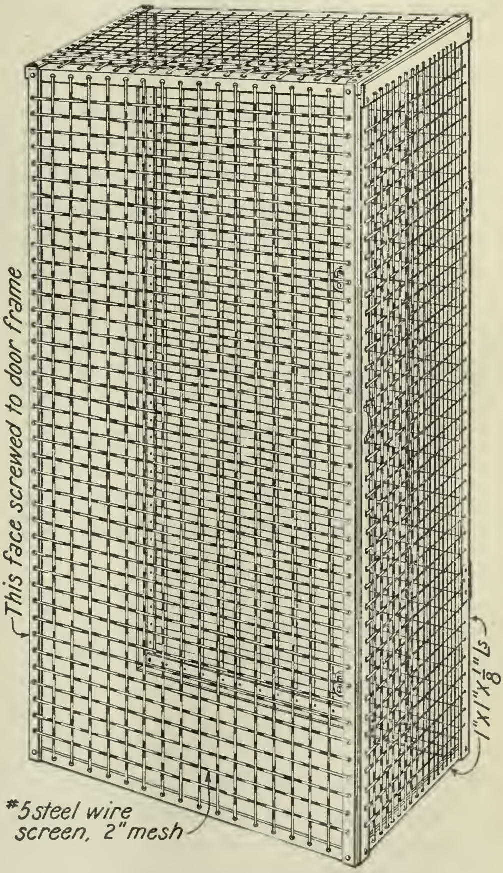

This face screwed to door frame
#5 steel wire screen, 2" mesh
1"x1"x⅛" Ls

FIG. 8.—Cage vestibule.

The cost of these buildings complete, including painting, is approximately 6 cents per cubic foot. For all the purposes of a camp of 40 convicts 10 of the 18-foot units are required, as follows:

For sleeping quarters of convicts	3
For kitchen and mess	3
For storehouse	1
For bathhouse	1
For office and superintendent's quarters	1
For quarters for foremen and guards	1
Total	10

With lumber at $20 per thousand, carpenters' labor at $2.50 per day of 10 hours, foreman's wages at $4 per day of 10 hours, and prices of hardware and miscellaneous supplies as in Fulton County, Ga., the cost of the complete equipment of 10 sections will be approximately $1,900, itemized as follows:

Lumber, 27,800 board feet, at $20 per M	$556
Hardware	397
Sashes, screens, and roofing	284
Carpenter, blacksmith, and machinist labor	400
Paint and painters' labor	263
Total cost	1,900

The cubic contents of the 10 buildings are 32,400 cubic feet. Therefore the principal items of cost per cubic foot are:

Lumber	$0.017
Hardware	.012
Sashes, screens, and roofing	.009
Carpenter, blacksmith, and machinist labor	.012
Paint and painters' labor	.008
Total cost per cubic foot	.058

It is estimated that the economic life of these buildings will be not less than five years, and upon this basis, with interest at 6 per cent per annum, it may be determined that their cost will not exceed 3.4 cents per convict per calendar day.

Complete plans and specifications for all-metal portable buildings and for buildings with metallic frames and canvas roof and sides are contained in a joint bulletin of the North Carolina State Board of Health and State Highway Commission.[1]

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[1] Joint Bul. No. 57, N. C. State Board of Health and State Highway Com.: "The Sanitary and Hygienic Care of Prisoners."

STRUCTURES WITH GALVANIZED-METAL ROOF AND CANVAS SIDES.

Buildings of this general type are in common use in the convict camps of Virginia. As shown in Plate XII, figures 1 and 2, they consist simply of a V-crimped tin or corrugated galvanized-iron roof laid on 1 by 10 inch purlins which rest on 2 by 6 inch rafters spaced about 3 feet on centers and braced with 2 by 4 inch ties. The rafters rest on 2 by 6 inch plates which are spiked to 6-inch rough posts, which in turn are planted about 3 feet in the ground. The gables usually are covered with metal of the same weight as that used in the roof and the sides are protected with drop curtains of 10-ounce duck. The continuous wooden platforms, 6 feet 6 inches wide, raised about 18 inches above the floor and extending along the two sides of the building in the sleeping quarters, take the place of separate bunks or cots. The pallets are laid on these platforms, side by side, with usually no space between them. The mess building, officers' quarters, and storehouses are similar in construction to the quarters or "cell house," the mess building, however, usually being unfloored.

The buildings in use in the Virginia camps are not fly-proof, and the investigation indicates that the cracks and crevices in the surface of the bunk platforms afford excellent lodging places for vermin and filth. These faults may be remedied by inserting screens between the 6-inch posts and by substituting separate metal cots for the wooden bunk platforms. If double, instead of single, decked cots be used, a wider separation of the inmates will be possible in quarters of the same size.

With these modifications, this general type of structure will be satisfactory for use during the summer throughout the United States and the year round in the extreme southern section. That it does not provide adequate protection against the winter weather in Virginia is the testimony of camp officials whose opinion was sought.

Buildings of this type may be considered relatively portable, and the use of the metal roof makes them somewhat more durable than tents, but they are neither so readily moved nor so durable as the portable buildings previously discussed. To provide for all the necessities of a camp of 40 men the following buildings of this type would be necessary:

One building 20 by 70 feet for convicts' sleeping quarters and clothes storage; one building 20 by 70 feet for dining room, kitchen, and pantry or commissary; one building 20 by 40 feet for office and officers' quarters and a wall tent 16 by 20 feet to be used for bathing purposes.

The estimated itemized cost of this equipment of structures is as follows:

Lumber, 14,000 board feet, at $18 per M	$252
Roofing, 20-gauge galvanized iron, 2½-inch corrugations, 6,000 square feet, at 11½ cents	690
Ridge roll, bolts, nails, etc	20
Canvas curtains, 10-ounce duck, 500 yards, 29 inches wide, at 27 cents per yard	135
Screens, 3,360 square feet, at 8 cents	270
Labor	300
16 by 20 foot wall tent, 12-ounce army duck	45
Total	1,712

Reducing this estimate to a cost per cubic foot, the costs of the principal items are as follows:

Lumber	$0.007
Roofing	.019
Ridge roll, bolts, nails, etc	.001
Canvas curtains	.003
Screens	.003
Labor	.008
Tent	.001
Total cost per cubic foot	.042

While the above cost is only a little more than two-thirds as great as that of the portable buildings designed by the Office of Public Roads and Rural Engineering, it should be borne in mind that those buildings are of a much higher type of construction and are suitable for winter as well as summer use. Furthermore, the canvas used in these buildings will have to be replaced every two years under normal conditions, and the metal roofing also will depreciate much more rapidly than any part of the portable buildings. For these reasons, notwithstanding their lower initial cost and narrower field of usefulness, it is believed that buildings of this general type will cost, in the long run, practically as much as the portable buildings previously described.

SHACKS.

Shacks of rough lumber made weather tight with a covering of tar-paper, similar to those used generally in free contracting camps, may be economically used for temporary camp purposes in sections where lumber is very cheap. Experience has shown that it does not pay to attempt to move them with the camp, the cost of taking them apart and the large proportion of lumber ruined being usually greater than the cost of new lumber.

Structures of this kind can be built for from 2½ to 3 cents per cubic foot.

PERMANENT FRAME STRUCTURES.

Structures of this type, similar to that shown in Plate X, figure 2, are used in the concentration or central camps of a few of the southern counties. In design, they are similar to frame structures used for other purposes, and hence they will be given no special treatment in this bulletin.

MISCELLANEOUS DATA ON BUILDING MATERIALS.

PAINT.

The solid ingredient of paint is called the pigment; and the liquid part, the vehicle. White lead and white zinc are the common white pigments, and the vehicle usually is linseed oil, with sometimes the addition of a little turpentine or other volatile solvent.

DRIERS.

These are compounds of lead and manganese dissolved in oil, and this solution thinned with turpentine or benzine. They act as carriers of oxygen from the air to the oil, and their addition to a paint makes it dry more rapidly. Not more than 10 per cent by volume of a drier should be added to oil.

PRIMING COAT.

This is the first coat applied to the clean surface. The priming coat for wood usually is made by thinning a gallon of ordinary paint with a gallon of raw linseed oil. In all woodwork, nail holes and other defects should be filled with putty after the priming coat has been applied; but if the wood be resinous, knots and resinous places should be covered with shellac before the priming coat is put on. Pitchy woods, such as southern yellow pine and cypress, do not absorb oil readily, and turpentine should be substituted for part of the oil.

SECOND AND THIRD COATS.

The priming coat, having been absorbed largely by the wood, a second, and possibly a third, coat of paint should be applied. The most common paint used on houses is white lead. This is commonly sold as paste white lead containing 8 per cent of oil, 100 pounds being equal to 2.8 gallons in volume, and it is commonly mixed with 3½ gallons of raw linseed oil, 1 quart of turpentine, and 1 pint of drier to make 6⅔ gallons of paint for the second coat, or with 4 gallons of oil, 1 pint of turpentine, and 1 pint of drier for the third coat. If a vehicle composed of half linseed oil and half turpentine be used in the paint for the second coat, it will have the effect of making the paint dry with a dull or "flat" surface instead of a glossy surface, and the third coat will adhere better. If white zinc is used, 9½ pounds of dry zinc oxide and 0.57 gallon of oil make 1 gallon of paint;

to this turpentine and drier also should be added. White lead is used everywhere, but tends to yellow somewhat in the dark. White zinc is used chiefly on interior work, being the whitest paint known. Colored paints are commonly made by adding colored pigments to lead or zinc. White, light blue, and light green are less durable than yellow, gray, or dark colors.

Painting always should be done in dry weather, and paint should not be applied to lumber that is not dry. A week or more should be allowed to elapse between successive coats. A gallon of paint will cover from 400 to 600 square feet of surface, depending upon the character of the surface.

WHITEWASH.

Ordinary whitewash is made by slaking quicklime in water in a pail or barrel covered with cloth or burlap. The proportions of lime and water should be about 10 pounds of the former to 2 gallons of the latter, and the lime should be allowed to slake for one hour. When the slaking is complete, enough water should be added to bring the whitewash to a consistency which may be applied readily.

Weatherproof whitewash for exterior surfaces may be made as follows:

(1) Slake 1 bushel of quicklime in 12 gallons of hot water; (2) dissolve 2 pounds of common salt and 1 pound of sulphate of zinc in 2 gallons of boiling water; (3) pour (2) into (1), add 2 gallons of skim milk, and mix thoroughly.

Roofing Materials.

PREPARED ROOFING.

There are on the market a large number of so-called "prepared" or "ready" roofings for covering the sheathing of wooden roofs. They are made by cementing together two, three, or more layers of tar-saturated felt or felt and burlap, then coating the combination either with a hard solution of the same cementing material or with a mixture of hot pitch or asphalt and sand or fine gravel. These roofings are commonly put up in rolls 36 inches wide and are applied by lapping the strips 2 inches, with a coat of cementing material between, and nailing every 2 or 3 inches with tin-capped roofing nails. A sufficient quantity of cement, nails, and tin caps is packed in the middle of the rolls. These roofings are especially suitable for use in convict camps, for the reason that no previous experience is required for laying them.

In the construction of the portable buildings previously described the prepared roofing can be fastened to the roof sections very satisfactorily with No. 9 flaked glue.

CORRUGATED IRON AND STEEL SHEETS.

Corrugated sheets of iron and steel, usually galvanized, are used frequently for roofing convict camps. The best grades are made of double-refined box-annealed iron or steel. The weight and thickness of the metal from which the corrugated sheets are rolled is represented by gauge numbers based on standard gauges established by act of Congress and known as United States standard gauge.

The following table gives the weights and thicknesses of the different gauges from No. 16 to No. 28, between which limits are included practically all the weights useful for ordinary roofing. Galvanizing the sheets adds about $2\frac{1}{2}$ ounces per square foot to the weights given.

United States standard gauge for sheet iron or steel.

No. of gauge.	Approximate thickness in fractions of an inch.	Weight per square foot in ounces.	No. of gauge.	Approximate thickness fn fractions of an inch.	Weight per square foot in ounces.
16	$\frac{1}{16}$	40	23	$\frac{9}{320}$	18
17	$\frac{9}{160}$	36	24	$\frac{1}{40}$	16
18	$\frac{1}{20}$	32	25	$\frac{7}{320}$	14
19	$\frac{7}{160}$	28	26	$\frac{3}{160}$	12
20	$\frac{3}{80}$	24	27	$\frac{11}{640}$	11
21	$\frac{11}{320}$	22	28	$\frac{1}{64}$	10
22	$\frac{1}{32}$	20			

The sheets generally used have corrugations measuring $2\frac{1}{2}$ inches from center to center. They are made in all gauges from No. 16 to No. 28, and are carried in stock in 4, 5, 6, 7, 8, 9, and 10 foot lengths, and can be obtained as long as 12 feet at a cost of 5 per cent extra per foot. The 8-foot length is most commonly used. The width of the sheets, as a rule, is 24 inches between the centers of the outer corrugations. All sheets are sold by the square (100 square feet), measuring the actual widths and lengths of the corrugated sheets.

The thickness or gauge required depends upon the distance between the supports on which the sheets are laid. The maximum distances between supports for the various gauges should be as follows:

For No. 26 to 28 gauge, from 1 to 2 feet, center to center.

For No. 24 gauge, from 2 to $2\frac{1}{2}$ feet, center to center.

For No. 22 and 20 gauge, from 2 to 3 feet, center to center.

For No. 18 gauge, from 4 to 5 feet, center to center.

For No. 16 gauge, 5 to 6 feet, center to center.

The least pitch which should be given to roofs that are to be covered with corrugated sheets is 3 inches to the foot, and the sheets, as laid on the roof, should have a lap at the lower end of from 3 to 6 inches, the larger laps being used on the lower pitches. For the side lap it is recommended that each alternate sheet be laid upside down and lapped as shown in (*a*) rather than (*b*), figure 9. By this method, when water is blown through the first lap, it will stop and not pass the half lap, but run down and out at the end of the sheet.

In applying to the sheathing or wooden strips, the sheets should be secured by nailing through the tops of the corrugations, the nails being driven through every alternate corrugation at the ends and about 8 inches apart at the sides.

In ordering corrugated sheets an allowance must be made for the laps. The following table (17) gives the number of square feet necessary to cover 100 square feet of actual surface, using sheets 8 feet long. If shorter sheets are used, the allowance must be slightly increased.

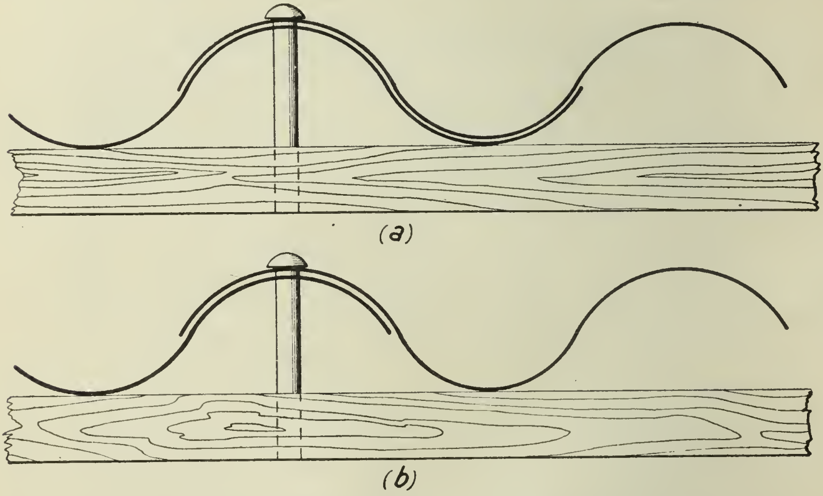

FIG. 9.—Proper (a) and improper (b) manner of laying corrugated roofing.

TABLE 17.—*Number of square feet of corrugated sheets to cover 100 square feet of roof.*

End laps.	1 inch.	2 inches.	3 inches.	4 inches.	5 inches.	6 inches.
	Square feet.	*Square feet.*	*Square feet.*	*Square feet.*	*Square feet.*	*Square feet.*
Side lap, one corrugation	110	111	112	113	114	115
Side lap, one and one-half corrugations	116	117	118	119	120	121
Side lap, two corrugations	123	124	125	126	127	128

CEMENT CONCRETE.

Portland cement concrete may be used in a convict camp for various purposes, such as the construction of floors, building foundations, well casings, and protective coverings, etc. Necessary information

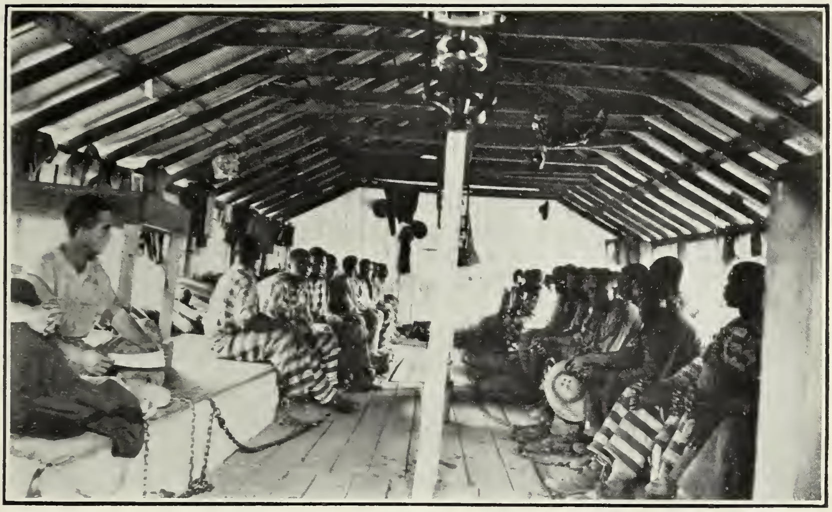

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FIG. 1.—INTERIOR OF VIRGINIA BUNK HOUSE.

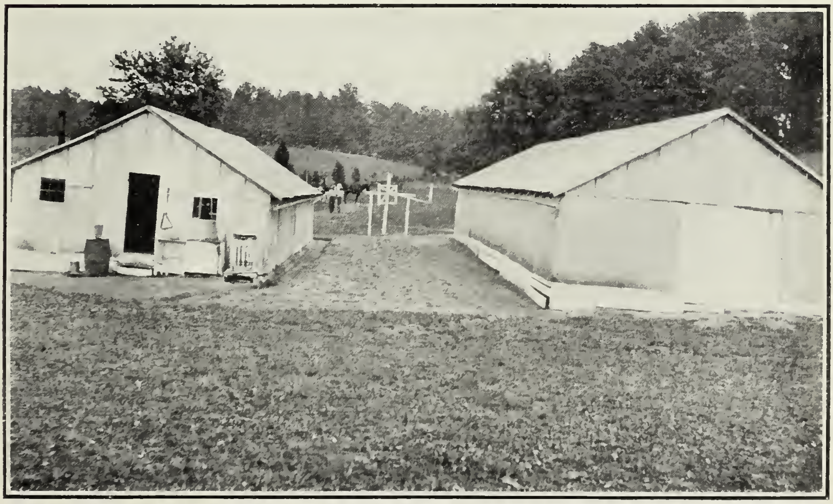

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FIG. 2.—EXTERIOR OF VIRGINIA CONVICT CAMP BUILDINGS.

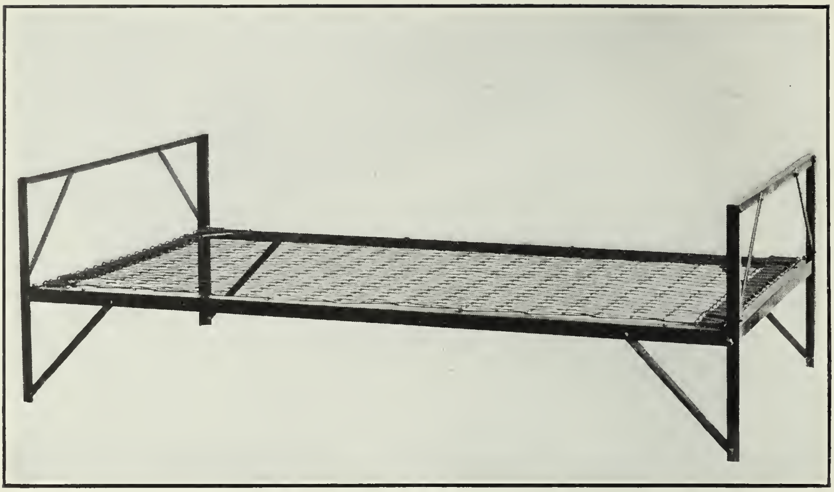

FIG. 1.—SINGLE-DECK METAL COT.

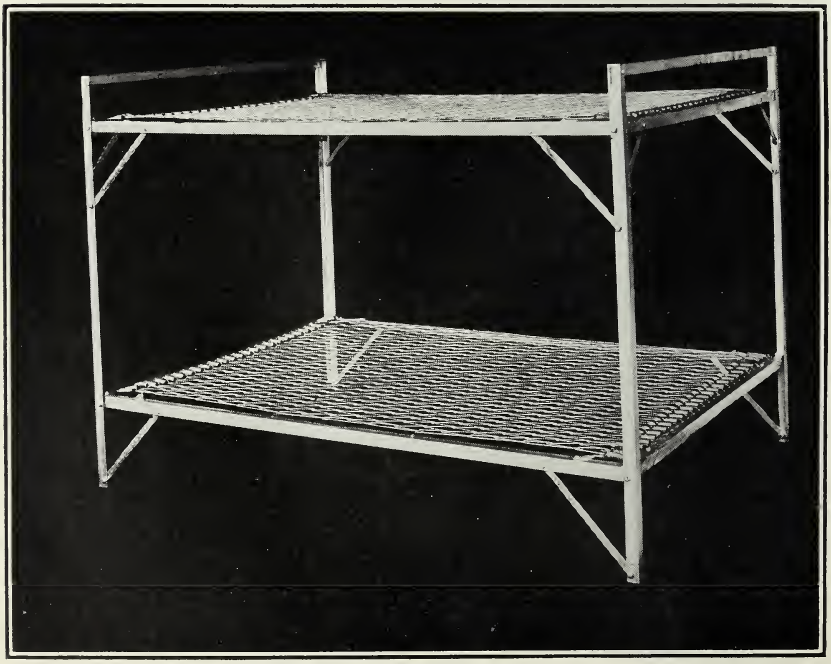

FIG. 2.—DOUBLE-DECK METAL COT.

with regard to the selection of the three ingredients, cement, sand, and stone, and the best methods of preparing the concrete, building forms, etc., is contained in Farmers' Bulletin No. 461, "The Use of Concrete on the Farm," prepared by the Office of Public Roads and Rural Engineering. Persons desiring copies of this bulletin may obtain them free from the United States Department of Agriculture, Washington, D. C.

CLOTHING, CAMP SUPPLIES, AND EQUIPMENT.

The problem of supplying and equipping a convict camp is a most complex one, and one which, for its handling, demands a broad study of the relative costs, durability, and suitability of the large number of trade articles and supplies which are available. Too often, in the hurry to put the camp into operation so as to realize the benefits of the convicts' work on the roads, the purchase of supplies and equipment receives but scant attention; articles are bought with little reference to their suitability and adequacy, to say nothing of their durability, simply because they are easily obtained locally. This haste results in rapid deterioration, discomfort, inconvenience, and loss of time which materially affect the economy of operation of the camp.

Though space does not permit a full discussion of all the items of supplies and equipment which have their places in a well-designed convict camp, and though the subject is such as to require particular study under the special conditions of each camp, a few of the more important items are discussed below from the standpoints of convenience, durability, and cost, and a number of other articles, with their approximate costs, are briefly listed. It is not considered that all the articles mentioned are necessary for all camps. They are given simply as suggestions of the articles available for supplying the clearly defined wants of convict camps, primarily with the purpose of recalling their availability to officials charged with equipping camps.

CLOTHING.

The clothing worn in convict camps varies considerably in quality and quantity; while the durability of various articles of the same grade, as reported from different localities, varies even more widely. This, however, may be expected to vary with climatic conditions and with the character of the work upon which the convicts are employed. In general, it will be found that the life of most articles of clothing will be shorter in a wet climate than a dry one; and such work as rock excavation and quarrying causes more wear and tear than those works on which the danger of tearing is less and the material handled is softer.

The principal items of clothing used in convict camps are: Coats, trousers, vests, underclothing, socks, shoes, shirts, nightshirts, hats or caps, and such special articles as slickers or oilcoats, rubber boots, fur-lined hats, and rubber capes.

The characters of the more important articles in use are stated below, the ranges of prevailing prices are given, and an estimate of the limits of durability is made on the basis of reports obtained in a number of widely distributed localities.

Coats, Trousers, and Vests.

The use of the vest as a prison garment is confined almost entirely to the Northeastern States. In these States it is generally made of woolen tweed and costs from 80 cents to $1. It is believed that it serves no useful purpose and is not recommended for general use.

Coats and trousers are made of cotton, wool, or part wool, and of solid gray, blue, and brown or in black and white stripes. The general practice in the Southern States is to provide 8 or 10 ounce woolen garments for winter use and 8-ounce cotton goods for summer wear. The woolen suits cost about $2.75 each, $1.50 for the coat and $1.25 for the trousers. The same weight of goods is used in stripes and plain material. It is customary to supply each convict with two full suits at one time, and the average wear of such goods is reported as from three to six months, depending on the nature of the climate and the service. A good rule, it is said, is to allow two of such suits per man for a winter season. For summer use the woolen clothes are replaced by cotton goods, of which the coats and trousers cost from 66 cents to $1 each. These also are supplied two at a time for each convict, and their average life is said to be from three to four months, the coats lasting somewhat longer than the trousers.

In the South the majority of reports indicate that each convict will wear out one woolen suit and two cotton suits each year, and that the average cost per man per year for these articles is about $6.50.

In the States of New York, New Jersey, and New Mexico a much heavier goods, in the nature of a woolen tweed, is used. Coats of this material are reported as costing from $2.85 to $3 each, and trousers from $1.78 to $1.90. But, though they exceed in first cost the quality of goods used so widely in the South, it is reported that their life greatly exceeds that of the latter. In New Mexico an accurate record kept at the State penitentiary shows a life of nearly two years for these garments, and in New York a life of more than one year is reported as the average. Usually the coat is not worn on the work, and the trousers are protected by overalls, which cost from 50 to 75 cents per pair and last from three to six months. Supplies of two pieces of each garment are maintained for each prisoner, as in the Southern States, and the approximate cost of coats, trousers, and overalls for each prisoner per year is from $6.50 to $7. In the States in which there is a penitentiary, the clothing for the road forces generally is made in the prison shops. In a number of the Southern States it is bought ready made from private manufacturers. In certain other States and counties the cloth is bought in large quantities and made into clothing by the female prisoners of the county or State, and as an instance of another method, in Chatham County, Ga., clothing for the road forces is made at the county courthouse by the poor people of the city of Savannah, who are paid at the rate of 5 cents per garment for cutting and from 10 to 14 cents for sewing.

Shirts.

Shirts usually are made of ticking, or cotton duck, though a cheap cotton madras is used in at least one State. In cost they range from 31 cents, as quoted in New Mexico, for a shirt of ticking, to 75 cents for an 8-ounce duck shirt in Fulton County, Ga., and $1 for a shirt of herring-bone material used in Arizona. According to the reports of durability, as made by officials in charge, all grades wear from six to eight months. In a number of the southern counties the shirts are worn without coats during the summer season. The average cost of shirts per convict per year is approximately $1.

Night Shirts.

The investigation showed that special garments for night wear were in use only in very few of the States, and these all in the Southeastern section. From a sanitary standpoint they are absolutely essential and from the standpoint of economy they are justified by the saving in wear of the underclothes. They also make possible a reduction in cost of laundering bed clothing. They are usually made of ticking at costs varying from 30 to 75 cents per garment, and wear from six months to one year. The average cost per man per year is 75 cents.

Underclothes.

Underclothes, shirts and drawers, usually are made of fleece-lined cotton or Canton flannel. Garments of the former goods cost about 37½ cents each for shirts and drawers, and of the latter goods 45 to 50 cents each. In the Southern States, as a general rule, underclothes are used in winter only. A life of from three to five months per garment is reported from a number of widely scattered localities, and the average cost per man per year for underclothing is $2.50.

Socks.

Socks for summer wear are made of cotton, for winter use of wool. The cost varies from 5 to 16 cents per pair and the life from 2 to 6 weeks per pair. The average cost of an equipment of socks is $1 per man per year.

SHOES.

The form of shoes usually provided is that known as brogans. In a number of the States the shoes used by the road-working convicts are made in the penitentiary shops. Some attempts have been made to prolong the life of shoes by reinforcing them with metal about the heel. These attempts, however, are not satisfactory, as the stiffness of the heel thus reinforced is a common cause of lameness which seriously impairs the efficiency of the workers. The costs of shoes used range from $1.37 per pair in Virginia to $3 per pair in Washington. The more usual costs are from $1.75 to $2.25, and the average cost is about $2 per pair. Reports of the life of shoes indicate that they will last under average conditions about 4 months; on rock work or work in marshes, however, their life probably will be shorter, and on light work somewhat longer than the average. The average cost of shoes per man per year as reported is $6.

HATS AND CAPS.

The hats and caps in use are of various forms, such as the ordinary convict-striped skull caps, golf caps, felt hats, and broad-brimmed straw hats. They vary in cost from 40 cents to $1 each and last from six months to one year. The average cost per man per year is approximately $1.

SPECIAL ARTICLES.

Besides the staple articles above mentioned a number of special articles are supplied for use in rainy and cold weather. Among these are slickers, or oilcoats, rubber boots, rubber capes, and warm hats and overcoats. Usually such articles are supplied for the use of only a part of the force for the reason that it is the practice to employ only a few men away from shelter in bad weather. It is a good policy to provide about a dozen of each of the articles in a camp of 40 men, and such supplies will last at least one year. The cost of each are approximately as follows: Slickers, $2 each; rubber boots, $2.40 per pair; rubber hip boots, $4.90 per pair; rubber capes, $1.75 each; warm hats lined with fur, $1 each. The average costs of all clothing may be approximately summarized as follows:

Item.	Quantity per year.	Cost per man per year.	Item.	Quantity per year.	Cost per man per year.
Coats	1 to 3	$3.50	Socks	8 to 24	$1.00
Trousers	1 to 3	3.00	Special articles, including slickers, boots, etc.		1.00
Shirts	2	1.00			
Night shirts	1 to 2	.75			
Underclothes	2 to 4	2.50	Total cost of clothing per man		19.75
Shoes	3	6.00			
Hats or caps	1 to 2	1.00			

COTS AND BEDS.

The usual forms of beds provided may be described as box bunks, pallets, wooden or Army cots, and metal cots. The box bunks consist simply of a rough box placed directly on the floor or elevated about 18 inches above it and usually filled with hay or straw upon which the bed covering is spread. The boxes sometimes are constructed in tiers, especially in the wooden cars. They are inexpensive, but apt to be very insanitary, and at best can only be regarded as makeshifts.

The pallets are made of mattresses, blankets, or quilts and are laid either directly on the floor or on continuous platforms, as in the Virginia camps.

The wooden cots usually are arranged to fold up and are either equipped with springs or made in the form of the Army cot, in which the springs are replaced by a sheet of canvas. These, as well as all forms of beds made of wood, are objectionable because it is difficult to keep them free from vermin. Metal cots were found in use in a few camps, in tiers in the steel cages and as single-deck or double-deck cots in the tents and wooden structures. These, as well as all other forms of beds, frequently are placed contiguous to one another.

The metal cot is by far the most desirable type from the standpoints of durability, economy, and cleanliness. They may be purchased at very reasonable prices from a number of manufacturers in various parts of the United States. The most suitable for the purposes of convict camps are those made of galvanized or aluminum-painted steel angles with sleeping surfaces of wire-link fabric, and helical springs at each end. In dimension they should be at least 2½ feet wide and 6½ feet long. They are manufactured in both double and single deck forms, and are so constructed as to be readily and quickly knocked down when the camp is moved. Desirable forms of double and single deck metal bunks are shown in Plate XIII, figures 1 and 2. A single-deck cot similar to the one shown can be purchased for not more than $3, and the cost of the double-deck cot will not be greater than $6. Bought in quantities of 25 or more it will be found usually that the cots can be supplied at about 20 per cent less than the foregoing prices.

BEDDING AND BEDCLOTHES.

For sanitary reasons mattresses stuffed with hay or straw are preferable to those filled with cotton batting. The ticks may be made very conveniently by women convicts, or in the penitentiary tailor shop. About 5 yards of ticking 36 inches wide are required for one tick, and the cost of the ticking is about 12 cents per yard, making the cost of a mattress tick about 60 cents for material alone. Such a tick will last about two years.

PILLOW TICKS.

Pillow ticks made of the same material as the mattress ticks and in the same way will cost about 18 cents each and last about the same length of time.

SHEETS AND PILLOW CASES.

At least four sheets, two sets of two each, should be provided for each inmate. The most suitable material of which to make them is unbleached cotton. About 3 yards of material will be required for each sheet, and, at the usual cost of 7½ cents per yard, a complement of sheets for one man will cost 90 cents. Each man may be expected to wear out two sheets a year, at a cost per year of 45 cents.

Pillow slips are as important as sheets and should be furnished. An allowance of two for each inmate should be made, and these will be worn out approximately at the rate of one per year. Each slip, made of unbleached cotton, will require 2 yards of goods, and the cost of one, as well as the cost per man per year, will be about 15 cents.

BLANKETS.

Gray cotton blankets, such as already are in use in a large majority of the camps, are the most suitable for the purpose. For a cot 2½ feet by 6½ feet they should be at least 5 feet by 7 feet in size, and enough of them should be on hand to keep the inmates comfortable without heating the sleeping rooms. This will require an outfit of at least 5 blankets per man, at a cost of 87½ cents each, or a total of $4.37. Under ordinary conditions each man will wear out one blanket a year, making the annual charge per man about 88 cents.

SUMMARY OF COST OF BEDDING.

The foregoing costs of items of bedding per man per year are summarized as follows:

Mattress ticks	$0.30
Pillow ticks	.09
Sheets	.45
Pillow slips	.15
Blankets	.88
Totol cost of bedding per man per year	1.87

TABLES.

Plans for the construction of a very convenient form of mess table with benches combined are given in figure 10. Each table 10 feet long will seat 8 men without crowding. In the interest of neatness it is desirable to cover the top with white oilcloth. The bill of materials for the table is as follows:

Lumber—
- 2 pieces, 1½ by 10 inches, 10 feet long, dressed four sides.
- 1 piece, 1 by 12 inches, 10 feet long, dressed four sides.
- 2 pieces, 1 by 10 inches, 10 feet long, dressed four sides.
- 3 pieces, 1 by 4 inches, 10 feet long, dressed four sides.
- 1 piece, 1 by 4 inches, 12 feet long, dressed four sides.
- 1 piece, 2 by 4 inches, 18 feet long, dressed four sides.

Oilcloth, 3½ yards.

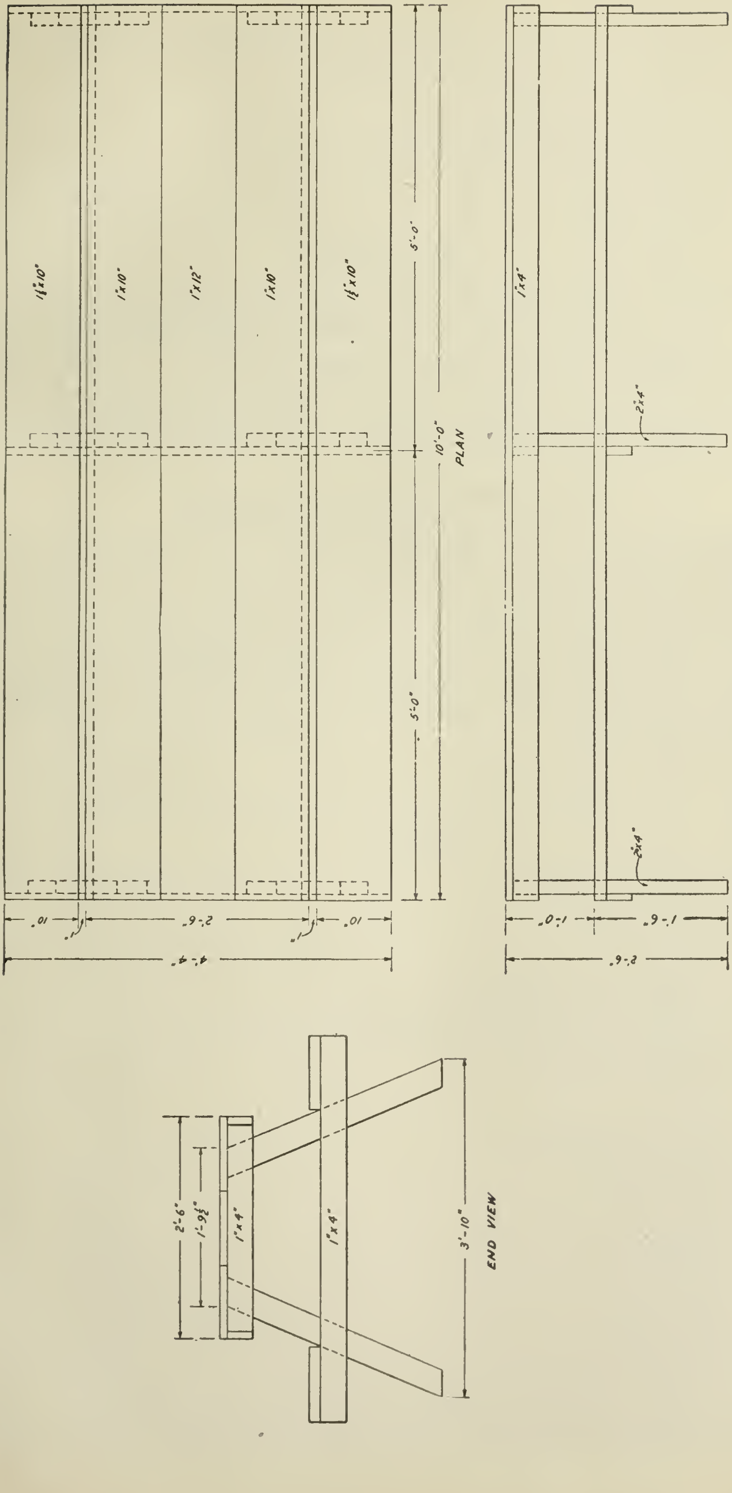

Fig. 10.—Details of mess table for convict camp.

Using yellow-pine lumber at $30 per M board feet, oilcloth at 25 cents per yard, and labor at $2.50 per eight-hour day the cost of such a table is approximately as follows:

Lumber, 78 feet b. m., at $30 per M	$2.34
Oilcloth, 3½ yards, at 25 cents per yard	.88
Labor, 2 hours, at 31 cents per hour	.62
Total cost of table	3.84

MESS UTENSILS.

The mess utensils commonly furnished to each prisoner are as follows: One tin dinner plate, one tin pint cup, one cheap metal spoon, and a tin dinner bucket of about 2 quarts capacity. In some camps knives and forks also are furnished. In general, the equipment furnished seems to be entirely suitable, but enameled-ware plates and cups are to be preferred to tinware.

SUMMARY OF SUPPLIES AND EQUIPMENT.

The prices given in the following summary are approximate only, and will vary from time to time and from section to section, but it is believed that they will give a fairly accurate idea of the relative cost of the various articles. All the articles are classified according to the grouping suggested under "Records and cost accounts," page 36, and the quantity of each article is that suggested for the stock of a camp of 40 convicts.

List of supplies, equipment, etc., for a camp of 40 convicts.

CLOTHING.

12 boots, rubber, knee length	per pair	$2.40
12 boots, rubber, hip length	do	4.90
Buttons, assortment.		
48 caps	each	.50
96 coats, cotton, stripes or plain color	do	.85
96 coats, woolen, stripes or plain color	do	1.50
96 coats, woolen tweed, stripes or plain color	do	2.90
96 drawers, fleece-lined cotton	do	.37½
96 drawers, Canton flannel	do	.50
48 hats, felt	do	1.00
48 hats, broad-brimmed straw	do	.20
50 pounds leather, sole	per pound	.43
96 nightshirts, ticking	each	.50
12 oil coats	do	2.00
96 shirts, ticking	do	.35
96 shirts, cotton duck	do	.75
96 pairs shoes	per pair	2.00
96 pairs socks, cotton	do	.07
96 pairs socks, woolen	do	.15
48 spools thread	per dozen	.50
96 trousers, cotton	each	.85
96 trousers, woolen	do	1.25

96 trousers, woolen tweed	each	$1.85
96 undershirts, fleece-lined cotton	do	.37½
96 undershirts, Canton flannel	do	.50
96 vests, woolen tweed	do	.90

QUARTERS.

Bolts, assorted.		
6 fire extinguishers	each	10.00
6 fire extinguishers	do	7.00
25 pounds floor filler	per pound	.10
100 gallons floor oil	per gallon	.50
2 glass cutters	each	.10
Hardware for buildings, assortment.		
Nails, assortment.		
2 putty knives	do	.10
Tacks, assortment.		
Washers, assortment.		
Window glass in size of lights	per square foot	.08

FURNITURE AND EQUIPMENT.

1 air compressor.		
1 air pump.		
1 air tank.		
2 alarm clocks	each	1.50
48 basins, enameled ware	do	.60
48 basins, tinware, capacity 3 quarts	do	.18
6 baskets, chip	do	.05
6 batteries, electric dry cell	do	.18
50 feet belt lacing, leather, ½ inch wide	per foot	.01½
200 blankets, cotton	each	.88
6 brooms, house	do	.40
2 brooms, whisk	do	.20
3 brushes, dust	do	.10
6 brushes, hair, stiff bristles	do	.35
3 brushes, paint, flat, 4-inch	do	.75
3 brushes, paint, flat, 2-inch	do	.50
6 brushes, scrub, stiff, white bristles	do	.15
3 brushes, shaving	do	.35
2 brushes, shoe (paste and polisher combined)	do	.25
2 brushes, stove (paste and polisher combined)	do	.15
12 chairs, folding arm	do	1.50
2 chamois skins	do	.50
12 checkerboards	do	.10
1 chisel set, ¼ to 2 inch sizes		3.30
2 chisels, cold	each	.25
1 pair clippers, barber's	per pair	2.50
2 gross clothespins	per gross	.80
200 feet clothesline wire	per foot	.004
1 clothes-washing machine	each	6.50
1 clothes wringer		4.00
6 coal hods, galvanized, large size	each	.50
6 combs, hair	do	.40
12 comforts, officers'	do	1.25
20 cots, double-deck, prisoners', 2 feet 6 inches by 6 feet 6 inches	do	6.00
40 cots, single-deck, prisoners', 2 feet 6 inches by 6 feet 6 inches	do	3.00

8 cots, single, officers', 3 feet by 6 feet 6 inches	each	$0.50
6 cuspidors, fiber, loose-covered	do.	.50
1 desk, flat-top.		
3 gallons disinfectant and sprayer		4.00
3 dustpans, household size	each	.15
500 sheets fly paper, at		5.50
12 fly swatters	each	.10
12 fly traps, wire style	do.	.12
6 garbage cans, heavy galvanized, capacity 25 gallons	do.	1.50
1 gas engine, 2¾ horsepower, at		62.75
1 grindstone, 24 inches, mounted, at		2.90
3 hammers, claw	each	.50
6 handlanterns, white globes	do.	.45
2 hatchets	do.	.75
1 hot-water heater, at		20.00
1 hot-water tank.		
24 lamp chimneys	each	05
12 lamps, wall, with reflectors	do.	.75
8 mattresses, cotton, 3 by 6 feet	do.	3.75
96 mattress ticks, 2 feet 6 inches by 6 feet 6 inches	do.	.60
2 monkey wrenches, small	do.	.50
12 mop heads	do.	.25
6 mousetraps	do.	.10
12 packages needles, large eyes.		
2 oiling cans	each	.40
20 yards oilcloth	per yard	.25
12 pails, galvanized wash, capacity three gallons	each	.35
96 pillow slips	do.	.15
48 pillow ticks	do.	.18
12 boxes polish, stove	do.	.10
3 razors	do.	1.50
1 razor strop	do.	1.00
1 saw, crosscut		1.60
1 saw, rip		1.60
1 scales, spring, 30 pounds capacity		3.50
3 screw drivers	each	.25
— pounds shaving soap	per pound	.25
3 shaving cups, glass	each	.25
1 shears, barber		.75
168 sheets, unbleached cotton	each	.23
2 shovels, fire	do.	.15
2 shovels, square point	do.	.50
144 bars soap, personal use	do.	.03
6 soap dishes, enameled	do.	.10
6 sponges, rough, large size	do.	.40
24 stools, camp, folding canvas seats	do.	.40
6 stoves, heating	do.	8.50
6 tarpaulins, 12 by 30 feet	do.	24.00
.. rolls toilet paper	do.	.05
50 yards towel, crash, at		1.75
144 towels, plain, Turkish	each	.10
4 washboards, glass front	do.	.50
4 washtubs, galvanized, capacity 20 gallons	do.	1.10
1 whetstone, at		.10

KITCHEN AND MESS SUPPLIES.

6 bread pans, sheet iron, 12 by 24 by 3 inches deep	each	$1.50
6 cake turners, handled	do	.08½
2 can openers	do	.10
1 cleaner, meat, medium size	do	.25
1 coffee pot, enameled, capacity 4 gallons	do	2.00
1 coffee grinder, mill style, capacity 1 pound	do	6.00
2 corkscrews, with patent lighting appliance	do	.25
12 glass cruets, with spring metal tops, capacity 1 pint	do	.15
24 cups, china	do	.07
48 cups, enameled, capacity 1 pint	do	.12
48 cups, tin, capacity 1 pint	do	.05
48 dinner buckets, tin, capacity 2 quarts	do	.10
12 dippers, tin	do	.05
4 dishpans, agate ware, capacity 6 gallons	do	1.00
2 forks, carving, galvanized, with wooden handle	do	.25
2 forks, cooking	do	.15
60 forks, table, nickeled ware	do	.07½
2 frying pans, 15 inches diameter, 2 inches deep	do	.90
2 frying pans, 8 inches diameter, 2 inches deep	do	.45
3 funnels, small, medium, and large sizes		.10, 15 and .20
1 grater, tin		.10
1 grinder, meat, large size		2.00
1 kitchen range, hotel style		
2 knives, carving	each	.30
60 knives, table, nickeled ware	do	.07½
3 ladles, soup, enameled, capacity 1 pint	do	.25
1 measure, half-bushel		.30
1 measure, pint		.25
1 measure, quart		.25
1 measure, half gallon		.40
1 meat block brush, heavy wire bristles		.15
1 meat saw		.35
2 milk cans, capacity 5 gallons	each	1.00
4 paring knives	do	.10
4 pepper shakers, table, aluminum, weighted base	do	.10
6 pitchers, enameled, capacity 6 quarts	do	.95
24 plates, China, dinner	do	.12½
48 plates, enameled, dinner	do	.12½
48 plates, tin, pie	do	.02½
1 gross cans potash	do	.05½
1 refrigerator		25.00
2 roast pans, double	each	1.50
1 rolling pin		.15
1 salt box, container size for cook		.25
4 salt shakers, table, aluminum, weighted base	each	.10
24 saucers, China	do	.07
4 spoons, cooking	do	.20
24 spoons, table, nickeled ware	do	.12
60 spoons, tea, nickeled ware	do	.07½
6 stew pans, agate, capacity 2 gallons	do	.50
1 stock pot, retinned, copper bottom, capacity 15 gallons		4.50
1 stock pot, retinned, copper bottom, capacity 10 gallons		3.50

1 stock pot, retinned, copper bottom, capacity 5 gallons		$2.50
6 sugar bowls, glass, with spring metal tops	each	.25
6 tables, homemade	do	3.84

FUEL AND LIGHT.

6 electric searchlights, hand size	each	1.50
50 gallons gasoline, variable, per gallon		
50 gallons kerosene, variable, per gallon		
10 tons coal, variable, per ton		

MEDICINE AND MEDICAL ATTENTION.

1 pound absorbent cotton		.25
1 spool adhesive plaster, 4 inches by 5 yards		.75
2 oz. alcoholic solution, iodine, 3 per cent	per ounce	.12½
2 oz. aqueous solution, boric acid, 4 per cent	do	.12½
2 oz. aromatic spirits of ammonia	do	.07½
100 aspirin tablets, 5-grain		.90
1 12-inch basin, enameled		.60
2 tubes, bicarbonate of soda in petrolatum, 3 ounce capacity	each	.15
100 bismuth subcarbonate tablets, 5-grain		.19
8 ounces boric ointment, U. S. P	per ounce	.04½
500 Brown's mixture tablets	per C	.14
100 calomel and soda tablets, one-half grain	per ounce	.12
16 ounces castor oil	do	.02½
3 tubes catgut sutures, sterilized, assorted sizes	per tube	.20
2 catheters, soft rubber	each	.20
16 ounces chloroform liniment	per ounce	.05
500 compound cathartic pills	per C	.20
1 pint eosol		.34
16 ounces Epsom salts	per ounce	.00½
1 eyecup		.10
1 roll gauze bandage, 3 inches by 10 yards		.10
1 roll gauze bandage, 2 inches by 10 yards		.10
1 roll gauze bandage, 1 inch by 10 yards		.10
5 yards gauze dressing	per yard	.06
½ pint grain alcohol	per pint	.60
1 pound green soap		.15
4 6-inch haemostats	each	.90
1 hot-water bag		1.00
2 ounces Jamaica ginger	per ounce	.07½
2 medicine droppers	each	.02½
1 medicine glass		.10
8 ounces mercurial ointment, U. S. P	per ounce	.09
1 nail brush		.05
2 packages opal silk	each	.25
8 ounces potassium iodide solution, 10 grains to the teaspoonful	per ounce	.09½
1 probe		.30
100 tablets quinine sulphate, 5-grain	per C	1.15
12 safety pins, large		.05
2 scalpels	each	.50
1 pair scissors, 4½ inches		.75
1 pair scissors, surgical, 6½ inches		1.25
8 ounces sodium bicarbonate	per pound	.15

2 splints, No. 1	each	$0.50
8 ounces sulphur ointment	per pound	.75
1 smooth-dressing forceps		.50
1 dozen surgical needles		.50
1 ounce toothache drops		.25

RATIONS FOR CONVICTS AT ROAD CAMPS.[1]

INTRODUCTION.

To maintain the body in the highest state of health and efficiency it must be supplied with those foods best adapted to build up the wasted tissues, furnish energy for the production of muscular activity, and yield heat for the upkeep of the temperature.

When a good variety of animal and vegetable foods is at hand in sufficient quantities, the instinct and taste of the individual generally may be relied upon to guide him in the selection of those foods best adapted to his needs, but when, through lack of means or deprivation of freedom, he is compelled to submit to certain limitations of his food necessity, rather than natural desire, may determine how his body shall be nourished. It is highly important, therefore, that those who are to restrict or supervise the feeding of any group of individuals should have some knowledge of foods and their relations to the human body.

Among the most important constituents of food are the substances known as protein, fats, carbohydrates, and mineral salts.

PROTEIN.

Protein is usually considered of first importance in food values, because it is the only constituent of food which contains nitrogen, the element essential for the building and repair of the nitrogenous tissues composing the body itself. Protein is contained in largest quantities and in forms most available to the body in lean meat, fish, cheese, eggs, milk, peas, beans, oatmeal, and wheat flour. It is noticeable that protein is in the greatest amounts and the most useful forms in the more expensive articles of food, and that fat meat, syrup, green vegetables, and molasses are not included. These latter foods, while by no means without great value in other ways, do not alone, with the possible exception of some green vegetables, supply the body with sufficient protein for its needs.

The results obtained from much careful study of different races and groups of individuals have led an investigator of wide experience in India to conclude that all successful people have habitually consumed protein in large amounts, whereas those who have adhered to a low protein standard have not progressed correspondingly physically, mentally, or morally. The following saying concerning the Brahmans, who are vegetarians, exemplifies the effects likely to accrue from foods deficient in proteins: "It is better to sit than to walk, to lie than to sit, to sleep than to wake, and death is best of all."[1]

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[1] Credit is given to the Office of Home Economics of the State Relations Service of this department for aid in the preparation of this part of the bulletin.

Dietary studies have shown that in communities where there exists a generally low condition of mental and physical efficiency, thrift, and commercial success, there, too, may be found a low proportion of proteins in the diet. As examples of this there are pointed out the negro and poor white of the South and the Italian laborer of southern Italy, all of whom are far down the scale as regards their sociological conditions and commercial enterprises and whose diet is very low in protein. Yet when "hog and hominy" are generally supplemented by a more liberal diet consisting of milk, eggs, meat, cheese, cowpeas, and beans their general condition and productive powers have been observed to increase markedly.

It is not denied that it is quite possible to maintain life, a certain degree of health, and a measure of strength on a diet somewhat low in protein, especially if the foods are selected carefully, have little waste, and are calculated to supply all the needed protein "building stones"; but the object to be attained is to provide that food which is best for the efficiency, economy, and general welfare of the body.

FATS AND CARBOHYDRATES.

The fats are contained principally in such foods as butter, oleomargarine, lard, salad oil, fat salt pork, bacon, and fresh meats and fish, while the carbohydrates include the sugars and starches and form the principal constituents of foods derived from plants. These foods can not build tissue, but they maintain the heat of the body and furnish energy to carry on the vital processes and for work and activity. The vegetable or plant foods also contain a considerable amount of indigestible material which affords no nourishment, but furnishes the bulk necessary to stimulate the flow of digestive juices and give the walls of the intestine something to work upon. If the food were all of such a character that it could be absorbed as total nutriment the bowels would not function properly and serious consequences would follow.

MINERAL MATTER OR ASH.

Mineral salts are required by the body for bone formation and other physiological processes. A generous and varied diet is much more likely to supply the required kinds and amounts of these essential constituents than is a diet restricted in quantity and variety. Fresh green vegetables and fruits are not of great value as tissue-building foods or energy producers and are not suitable to use as substitutes for the more substantial foods, but they contain considerable amounts of mineral salts, which are as essential to the health of the body and its vital processes as are other food constituents and should always be given a place in the diet for this reason. These also are useful for increasing the bulk in a diet which is already sufficiently nutritious but lacking in amount. Then, too, as Dr. Langworthy has observed,[1] the use of fruits, fresh and preserved, often makes palatable an otherwise rather tasteless meal. Jam with bread is a reasonable combination, the highly flavored fruit product whetting the appetite for the needed quantity of rather flavorless bread.

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[1] D. McCay, "The Protein Element in Nutrition."

From the preceding paragraphs it is evident that various kinds of food are necessary if the body is to be well nourished. It now remains to be seen in what combination these articles of food should be selected and in what quantities they should be provided.

It has been shown already that a certain amount of protein food is necessary. Under ordinary conditions of life natural tastes and desires generally lead to the selection of suitable foods, and so it comes about that the common articles of food consumed by the great majority of people in good health consist of meats, fish, eggs, milk, butter, cheese, sugar, flour, meal, cereals, fruits, potatoes, and other vegetables. In such foods as these there is plenty of protein material, and when the amount of food consumed is sufficient to satisfy the appetite and produce a feeling of satisfaction there is no doubt but that the body is supplied with a store from which it may pick out those combinations so essential to its nutrition. When, however, economic conditions become such that the more expensive elements (meat, fish, eggs, milk, and cheese) must be curtailed and the diet must be limited to a few articles of food, and those the very cheapest, care must be taken to provide a sufficient amount of proteins.

A diet consisting of salt fat pork, corn meal, a little white flour, syrup or molasses, and a few green vegetables and fruits is high in fats and starches but low in protein. Salt fat pork consists almost wholly of fat, and while it adds much to the energy value of the diet it is very low in protein (tissue-building substance). The other foods also are low in protein, so that the diet is one-sided and poorly balanced. Taken as a whole, the people who live largely on a diet of this sort are more liable to diseases of nutrition (scurvy, beriberi, pellagra) and are neither so robust, active, nor productive of efficient labor as others who are more fortunately situated. Combined with foods of this sort there must be protein foods, such as beans, cowpeas, salt fish, and any others that can be afforded if a suitable diet is to be provided.

THE FOOD IN CONVICT CAMPS.

It is reasonable to assume that the food furnished to convicts at work on the public highways while serving their sentences should be wholesome and nutritious but that the cost should be as low as is consistent with proper nourishment. In what ways the problems of feeding presented themselves to the various camp officials and with what success they were solved will now be discussed.

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[1] U. S. Department of Agriculture: Farmers' Bulletin 293.

In general, it may be said that a wide variation exists in the quality and kind of food furnished at different camps, but without exception the quantity served was always sufficient to satisfy the desires of the men. The greatest differences in food were apparent between the camps in the Southern States and those in the East and West. In each of these sections of the country, however, the prisoners received the kinds of food to which they were accustomed and which seemed to be adapted to their particular needs.

At honor camps the quality of the food is always a prominent feature, because it is hoped that by making the diet attractive and adding certain delicacies the men may be made more contented and less liable to attempt to escape. Numerous articles of food in the dietaries of honor camps are not, therefore, justified on the basis of food values alone, and the cost of feeding does not represent the lowest price for which the proper amount of nourishing food can be provided. In fact, the food frequently is of a higher grade than that which the average laboring man is able to provide for himself and his family. At certain camps the food is so attractive and the quantities so liberal that overeating is a common cause of sickness. Men accustomed to prison fare for long periods of time are especially prone to disturbances of digestion when indulging to excess in the tempting viands of the honor camps.

The following menus in effect at one of the eastern camps visited may serve as examples of the food served at several camps of this type:

Breakfast:
    Fried breakfast bacon and eggs (2 slices of breakfast bacon and 2 eggs to each man).
    Fried potatoes.
    Bread and butter, or hot biscuits and butter (without stint).
    Coffee, with sugar and fresh milk.
Dinner:
    Beefsteak with onion gravy, tomato catsup; or pork chops; or roast meat.
    Mashed potatoes.
    Stewed tomatoes or other vegetable.
    Bread and butter (without stint).
    Mince pie, or pudding, or some other dessert.
    Coffee, with sugar and fresh milk.
Supper:
    Scrambled eggs, or poached eggs on toast (2 to each man).
    Hot biscuits and butter.
    Stewed fruit.
    Cookies or cakes (freshly baked at camp).
    Hot cocoa, fresh milk.

This camp consisted of 18 white prisoners and the cost of the rations was estimated by the camp officials at 30 cents per person per day, which, however, did not include the cost of fresh milk, butter, and eggs. The latter supplies were furnished to the camp by the county in which the men were at work.

The estimated cost is remarkably low for the kind of food furnished, but the camp was located favorably in a rich farming district, and supplies were purchased at an unusually low price.

A diet such as this leaves nothing to be desired as far as general nutritive properties and the pleasure of taste are concerned, but it is largely composed of the more expensive articles of food for which cheaper substitutes might be found readily. Only under exceptional conditions can food of this sort be provided, and for economic reasons its use is quite impractical.

Following is another menu at one of the eastern camps:

Breakfast:
  Oatmeal mush; beef hash, or steak, or ham, or bacon, or eggs.
  Bread and butter (without stint).
  Coffee, with diluted evaporated cream sweetened to prevent waste of sugar.
Lunch (on road):
  Three sandwiches of the following kinds: ham, egg, corned beef, roast beef, bacon, or cheese.
  Tomatoes or fruit.
  Cold coffee or tea.
Dinner:
  Soup or chowder (three times a week).
  One of the following dishes: Roast beef, boiled ham, corned beef and cabbage, boiled beef, Hamburg steak, mutton potpie, beef stew, pork and beans, or fresh fish.
  Boiled or mashed potatoes.
  Stewed corn or rice, or beans or peas, or some other vegetable.
  Bread and butter.
  One of the following kinds of dessert: Pie, pudding, sweet buns, coffee cake, or stewed fruit.
  Coffee, tea, or cocoa, with diluted evaporated cream sweetened.

This camp was composed of 60 white prisoners. A contract had been made for the feeding of the men at the rate of $2.50 a week per man (about 36 cents per day), which included the cost of hauling all supplies for a distance of about 12 miles. The food was prepared and served by prisoners under the supervision of the contractor.

The articles of food furnished comprise a well-balanced mixed diet of considerable variety, with fresh meat in one form or another two or three times a day, but in spite of this the prisoners were dissatisfied and with just cause. The food was served in an unappetizing manner and was poorly apportioned; lunch pails were partially filled the day before they were to be used and were allowed to stand in a warm place so that the contents soured or became stale; and the general supervision was lax. This is a good illustration of the fact that a high grade of food may be distasteful if prepared and served in a careless manner. These men undoubtedly would have been better satisfied with cheaper articles of food carefully prepared and decently apportioned and served. This was the only honor camp visited in which a contractor was given supervision of the feeding, and it is interesting to note that it is also the only camp at which any complaint was heard in regard to the food.

Following is a menu of a western camp:

- Breakfast:
  - Cereal (oatmeal mush, hominy, or corn-meal mush), with condensed milk and sugar.
  - Fried bacon.
  - Bread, with corn sirup.
  - Coffee, with condensed milk and sugar.
- Dinner:
  - Fresh meat (beef, mutton, or pork).
  - Potatoes.
  - One other vegetable, including a variety of fresh vegetables in season.
  - Bread.
  - Fresh or preserved fruit.
- Supper:
  - Meat stew, or cold left-over meat, or pork and beans.
  - One or two fresh vegetables, or canned vegetables when fresh vegetables are not available.
  - Bread.
  - Stewed fruit or fresh fruit.
  - Coffee with sugar and condensed milk.

Vienna sausage, macaroni, and cheese also were used for varying the diet.

This camp was composed of 70 prisoners. The food was well prepared by a good cook and neatly served. It furnishes an excellent example of a moderate-priced, well-balanced diet for men at hard muscular labor. The average cost of the ration was 28.8 cents notwithstanding the fact that the camp was located 20 miles or more from the source of supplies.

It should be noted that breakfast consists mainly of cereal, bacon, and bread. This is a nutritious, convenient, and economical meal, and does not require the addition of meat or eggs to make it rational as long as the quantity served is sufficient to satisfy the appetite. Whatever constituents may be lacking will be made up readily at the next meal which consists of meat, vegetables, and fruit.

Dinner is seen to consist of plain substantial food materials, with fresh or preserved fruit in place of pies, puddings, or cakes. Not only are the fruits less likely to cause distress or digestive disturbance than the latter more elaborate and expensive combinations, but they are especially valuable because of their mineral constituents which are needed by the body.

Supper is a well-balanced meal made up from left-over meat and vegetables with an occasional extra dish for variety. Butter is entirely absent from the diet, the fat being furnished by the bacon and the meats.

Another western camp menu is as follows:

- Breakfast:
  - Oatmeal or corn-meal mush.
  - One of the following: Fried steak and onions; fried ham; breakfast bacon; fried liver; corned-beef hash.
  - Potatoes (fried, stewed, or potato chips).
  - Bread.
  - Sirup.
  - Coffee, with evaporated milk and sugar.
- Dinner:
  - Soup (four times a week), tomato, cream of tomato, rice and tomato, or split-pea.
  - One of the following: Roast beef with brown gravy, and macaroni and cheese; short ribs of beef; boiled ribs of beef; stewed beef; braised ribs of beef with tomato sauce.
  - Potatoes (mashed, browned, or boiled).
  - Pink or navy beans and rice, or turnips, or macaroni, or cabbage.
  - Dessert (four times a week): Apple roll, raisin roll, or cottage pudding.
- Supper:
  - Beef stew, or fried hash, or chili con carne, or boiled beef.
  - Always one of the following: Stewed navy beans, pink beans, or baked beans.
  - Raw cheese and onions (two or three times a week).
  - Always one of the following: Stewed prunes; stewed apples; stewed raisins.
  - Bread.
  - Coffee.

All of the food materials included in this diet are wholesome and nutritious, but a much greater variety than is necessary is furnished at each meal. The redundancy may best be discerned by comparison with the preceding menu.

Soup may be considered a luxury and is justified only when the ingredients for its concoction are at hand and no extra expense is incurred in its preparation. It contains in itself very little nutriment, but is useful for soaking bread and adding to foods which otherwise would be too dry.

Such combinations as meat and macaroni and cheese, or meat and stewed dried beans, or meat and cheese are both costly and unnecessary. All these are the more expensive foods, rich in proteins, and a sufficient quantity of one of these dishes at a meal will give fully as much satisfaction. Then, too, when two or more rich protein foods are provided at one meal the opportunity for variety is greatly reduced—the greater the number of food materials served at one time the oftener they must appear, and the more monotonous they will become.

The cost of this ration in a camp of about 50 men was 41.4 cents, which is more than the average free laborer could afford at his own home.

In the honor camps of the State of Washington the variety of foodstuffs used and the amounts in which they were apportioned were based to a certain extent upon the garrison ration of the United States Army. The camp cooks were given lists of the foods with the quantities allowed each man, and using the amounts designated they selected the food materials and prepared the meals for their respective camps. All food supplies for the day were weighed out each morning, and records of the amounts used were sent to the office for filing. In this way it was possible to keep accurate cost data and to account for all food materials purchased for the camp.

At the guarded camps this system was quite satisfactory and the men were well fed at an approximate cost of 29 cents a man per day; but at the honor camps the principles of the Army ration were not strictly adhered to and butter, eggs, pies, cakes, canned fruits and vegetables, and preserves, were used to such an extent that the cost of the ration was at times well over 50 cents.

The diets shown thus far include most of the foods which are in common use throughout the country and are a fair indication of the kinds of food served in camps composed mostly of white prisoners in the Eastern and Western States. They contain a considerable variety of foods, both animal and vegetable, and in general represent those combinations which years of experience have proved suitable for supplying the needs of the body.

The average cost of camp rations in the Eastern and Western States visited is as follows: New York, 32.9 cents; New Jersey, 34.5 cents; Michigan, 40 cents; Colorado, 28.8 cents; Utah, 25 cents (estimated); Wyoming, 45 cents (estimated); Washington, 42 cents; Oregon, 50 cents (estimated); Arizona, 41.4 cents; New Mexico, 45 cents. General average, 38.5 cents.

In convict camps in the South the negroes form by far the largest proportion of the population and the food requirements are somewhat different from those of the white prisoners. The food which they like and to which they are accustomed, consists mainly of salt fat pork, corn meal, white flour, molasses, salt fish, cowpeas, beans, potatoes, and a limited amount of green vegetables and fruit. These foods may be combined in such a manner as to make a well-balanced diet quite suitable for supplying the needs of the negro laborer. When the diet is limited to these few articles of food, however, much greater care is necessary in order that the protein content may not fall too low. Cowpeas, beans, and salt fish contain protein in greater proportions than the other foods and it is very important that these should be served regularly and in suitable amounts. Without their use the diet will become one-sided, and the consequences previously mentioned in connection with insufficient protein will follow.

In all southern convict camps it is the endeavor to serve fresh meat, usually beef, either once or twice a week. This forms a very valuable addition to the diet in the way of protein food, and is a pleasing variation from the regular bill of fare. The proportion of fresh meat used is, of course, very small as compared with the amount furnished in the diets of the eastern and western camps. It is estimated that in the average diet in the southern camps beans and peas furnished about 22 per cent of the total proteins and 8 per cent of the total energy, while in the ordinary diet of the free working man beans and peas form from 3 to 4 per cent of the total proteins and 1 per cent of the total energy, the difference being made up largely of the higher priced animal protein of fresh meat.

It is well known that the protein constituents of fresh meat and fish are more like the human body in composition, and so are more thoroughly digested and assimulated than the protein of peas and beans, and a common experience after eating these latter foods in any quantity is the occurrence in the intestines of what is known as flatulence or gas. Convicts at hard labor on the roads, however, seem to experience little difficulty in digesting these foods and in assimilating a high percentage of their proteins. The fact that peas and beans are furnished as a regular part of the ration, and in combination with such other foods as salt pork, bread, vegetables, salt fish, molasses, and coffee is important, because it probably makes their digestion and assimilation more thorough. At most convict camps the ration of dry peas or beans seldom exceeds 4 ounces. This is an amount which experience has shown to be reasonable in the diet of a man at hard labor, but it is doubtful if the quantity should be exceeded except under extraordinary circumstances.

That the food provided is satisfactory in general is best shown by the testimony and state of nutrition of the convicts themselves. They do not complain of the food, although perfectly free to find fault with other conditions. Save an occasional longing for a lemon, a pickle, a piece of cake, or some ice cream, they have no suggestions to offer in regard to the diet, and express themselves as being well satisfied.

Negro convicts at work on the roads were serving sentences of from 10 days to life, and although the majority were perhaps short-term men, a number of prisoners who had lived in the camps for periods of from one to seven years came under observation. These men were almost invariably well nourished and in good condition as far as the effects of food were concerned. While it was impossible, in the time available, to obtain records of the loss or gain in weight of convicts assigned to road camps, it was asserted very generally and emphatically by camp physicians and superintendents, prison officials, and others having an intimate knowledge of convict camps, that there was, as a rule, a distinct gain in weight and a general betterment in the physical condition of the men after entering the camp. Of this there is scarcely a doubt, for although camp conditions may be far from what they ought to be, they are in many cases better than those to which the prisoners have been accustomed before their arrest, and they are most assuredly far superior to those of many of the jails in which men are oftentimes confined for several months before sentence to the road camps. In writing of the food in the jails of one of the Southern States, the State prison inspector says:

> Prisoners in the jail of —— are fed by the sheriffs without supervision of any kind whatsoever. The food usually consists of a small piece of salt side meat, about three tablespoons full of beans or peas, and a "hunk" of poorly made corn bread, said bread usually being made of meal and water without grease. The sheriffs are recompensed by the State for feeding the prisoners as follows: From 1 to 10 prisoners, for each prisoner, 60 cents per day; for more than 10 and not exceeding 20 prisoners, 50 cents per day; for more than 20 and not exceeding 40 prisoners, 40 cents per day; for more than 40 prisoners, 30 cents per day. In most of the jails only two meals are served daily.
>
> I estimate (and base my figures on frequent inspections and close observations of the meals served, and from reports received) that in one jail in our State the profit to the sheriff is no less than $1,000 a month on his feed bill alone. This is a woeful waste of the State's funds, and should be remedied by some legislative enactment.

Surely the road camps are an improvement over this, and a gain in weight after a period in jail is to be expected.

Diseases such as scurvy, beriberi, and pellagra, which might result from a one-sided or eccentric diet, were diligently sought for, but were conspicuous by their absence, with the single exception of a camp in South Carolina, where, in 1910, 17 cases of beriberi had occurred, and in 1914 five cases of pellagra had developed, resulting in two deaths. It was impossible to obtain from the records of this camp accurate detailed information in regard to the kinds of food which had been used and the amounts consumed, but it may be said safely that such information, could it be accurately obtained, would reveal the fact that the food actually consumed by the stricken men was in some way faulty. It was said that in 1910, when beriberi broke out at the camp, the diet consisted of hominy, salt pork, some kind of fresh vegetable every day, corn bread and molasses, and occasionally potatoes. Fresh meat usually was provided about twice a week. Rice never was served. After the occurrence of the 17 cases of beriberi the location of the camp was changed, and the diet received additions in the form of peas, beans, salt herring, canned tomatoes, white bread, and rice. These foods are now served as follows:

- Breakfast:
    - Hominy grits.
    - Fried bacon.
    - White bread.
    - Molasses.
    - Coffee with sugar.
    - Canned tomatoes (average two days a week).
    - Salt herring (average one day a week).
- Dinner:
    - Stewed beans, or stewed cowpeas, or Irish or sweet potatoes, or cabbage (rarely), or green vegetables.
    - Boiled rice (daily).
    - Boiled bacon.
    - Bread (very seldom have bread for dinner).
- Supper:
    - Hominy grits.
    - Fried bacon.
    - White bread with sugar or sirup.

Corn meal is very seldom used at this camp. Fresh meat is supposed to be served once a week, but it is not always possible to obtain it as often as that, and at the time of the visit the cook said that no fresh meat had been served for two months.

After this diet had been in use for about a year, two cases of pellagra developed. They are reported to have recovered after two or three months with no special treatment and no change of diet. From that time up to 1914 sporadic cases have occurred, but have seemed to recover. In 1914 four more cases of pellagra developed, all at about the same time. Two of the stricken men had been in the camp for more than a year, and the other two for about four months each. Two of these cases died in about six months from the time the disease was first noticed, and the other two made an apparent recovery, and were discharged from the camp at the expiration of their terms.

The following tables are fair examples of the meals served in convict camps in the Southern States:

VIRGINIA: COST OF RATION ABOUT 11 CENTS PER DAY.

The food materials and the quantities in which they are intended to be used are as follows:

	Ration (ounces).		Ration (ounces).
Salt fat pork (plates)	7	Salad	13
Fresh meat (Sundays and holidays)	12	Turnips	16
White flour	8½	String beans	13
Corn meal	7⅙	Rice	1⅚
Dried beans or peas	5⅓	Dried apples or peaches	2⅔
Salt fish	4	Sugar	¼
Potatoes	16	Molasses	4
Cabbage	13	Coffee	⅓

These foods are commonly served in the following manner:

Breakfast:
- Fried salt pork.
- White biscuit (three times a week).
- Corn bread (four times a week).
- Molasses.
- Coffee.

Dinner:
- Stewed beans or peas, or one other vegetable.
- Boiled pork (cooked with the beans or vegetable).
- Corn bread.

Supper:
- Salt herring.
- White biscuit (three times a week).
- Corn bread (four times a week).
- Stewed dried fruit.
- Molasses.

A stew of fresh meat and vegetables is provided on Sundays and holidays, and peas or beans are served four times a week, on an average. A dinner consisting of boiled pork, corn bread, and some vegetable is served about twice a week.

At one Virginia camp the officer in charge was able to raise fresh vegetables at the camp and to furnish the men with a greater variety of food than would have been possible otherwise. The money saved by raising vegetables at the camp was expended in pickles and a few other luxuries, which added vastly to the satisfaction of the men.

North Carolina: Cost of Ration About 21 Cents.

Breakfast:
- Fried salt pork.
- White biscuit.
- Molasses.
- Coffee, with sugar.

Dinner:
- Stewed peas or beans (about three times a week) or cabbage or Irish potatoes or any other vegetable procurable.
- Boiled salt pork.
- Corn bread.

Supper:
- Fried salt pork.
- Corn bread or white biscuit.
- Fresh beef (served twice a week).
- Bread pudding or preserves (served once a week).
- Molasses.
- Coffee.

South Carolina: Cost of Ration About 18 Cents.

Breakfast:
- Hominy grits.
- Corn bread or white biscuit.
- Fried salt pork.
- Coffee (not every day).
- Buttermilk on an average of once in two weeks.
- Molasses.

Dinner:
- Stewed peas or beans (about four times a week) or potatoes or cabbage or greens or any other vegetable procurable.
- Soup at rare intervals.
- Boiled salt pork.
- Corn bread.
- Molasses.

Supper:
- Same as breakfast, except flour bread instead of corn bread and salt fish instead of pork sometimes.

Fresh meat is served once a week when it can be obtained.

Georgia: Cost of Ration About 20 Cents Per Day.

The Prison Commission of Georgia has prescribed the following ration list as the minimum food allowance which may be given to convicts employed in the road camps:

	Ounces.		Ounces.
Salt pork	12	Sirup (3 times a week)	2
Fresh pork, beef, mutton, or kid (twice each week)	16	Vegetables (3 meals a week)	6.4
Corn meal	9.6	Coffee (1 cup at breakfast)	.32
Wheat bread (3 meals per week), flour...per meal	2.4	Salt	.64
Baking powder	.16	Pepper	.02
		Vinegar	.32

The meals actually served at the camps are more liberal than these allowances would indicate. The following is a fair sample:

Breakfast:
- White biscuit (from 2.4 ounces flour).
- Fried salt pork, 4 ounces.
- Molasses.
- Coffee.

Dinner:
- Fresh meat, 16 ounces (two days a week).
- Stewed peas or beans, 4 ounces (three or four days a week).
- Some seasonable vegetable when peas or beans are not given.
- Boiled salt pork, 4 ounces (when fresh meat is not provided).
- Corn bread (as much as desired).

Supper:
- Salt fish, 5 ounces.
- Boiled rice or left-over vegetable.
- Corn bread.
- Molasses.

Many of the camps are supplied with fresh vegetables raised on the convict farms. An attempt is made to vary the vegetables as much as possible.

Florida: Cost of Ration About 25 Cents.

Breakfast:
- Rice or hominy grits.
- Corn bread or white biscuit.
- Fried salt pork (with tomato sauce occasionally).
- Coffee, with sugar and condensed milk.
- Molasses.

Dinner:
- Fresh meat (twice a week).
- Stewed peas or beans (three or four times a week).
- Some readily procurable vegetable when peas or beans are not used.
- Boiled pork (cooked with beans or vegetables).
- Corn bread.

Supper:
- Cabbage or turnips or potatoes or yams.
- Fried salt pork.
- Corn bread.
- Molasses.

Alabama: Cost of Ration 12 to 15 Cents.

Breakfast:
- Hominy grits.
- Hashed or browned potatoes with gravy or salt pork.
- White bread.
- Coffee, with sugar.

Dinner:
- Stewed peas or beans or boiled cabbage once a week.
- Boiled salt pork.
- Corn bread.

Supper:
- White bread.
- Cold beans or peas (if desired) or salt fat pork.
- Molasses.
- Coffee.

Beef stew with Irish potatoes is served once a week, and sweet potatoes, boiled or baked, are served twice a week in addition to the regular food.

Texas: Cost of Ration about 33 Cents.

Breakfast:
- Boiled rice.
- Hot biscuits.
- Fried potatoes.
- Fried salt pork.
- Molasses.
- Coffee.

Dinner:
- Fresh meat twice a week.
- Stewed beans or peas (daily except when fresh meat is used).
- Boiled cabbage, or potatoes, or some other vegetable (daily).
- Boiled salt pork.
- Bread pudding or stewed fruit.
- White or corn bread.
- Coffee.

Supper:
- Hot biscuits.
- Cold left-over vegetables.
- Fried salt pork, or cold left-over meat.
- Molasses.

This is an excellent bill of fare. The camp, however, was composed entirely of white prisoners who were working under the honor system.

In only one camp visited was the following type of "contract" system in use. The superintendent had the contract for feeding the men and received 40 cents apiece per day for the first 20 men and 35 cents for each man over. The camp was composed of 45 convicts. The following table is a comparison between the food served at this camp under the contract system and the food served at a similar camp in an adjoining county where the bills for food were paid directly by the county. The food at both camps was satisfactory in regard to quantity served.

COST OF FOOD SUPPLIED BY CONTRACT AND BY COUNTY.

Food by contract at 40 cents for first 20 men and 35 cents for each man after—45 convicts.

- Breakfast:
  - Grits.
  - White biscuit.
  - Fried bacon.
  - Molasses.
  - Coffee with sugar.
- Dinner:
  - Stewed beans, or peas, or cabbage.
  - Boiled bacon.
  - Irish or sweet potatoes.
  - Corn bread.
  - Fresh green vegetables occasionally.
  - (Fresh meat on Sunday.)
- Supper:
  - Same as breakfast, except rice instead of grits.

Food paid for directly by county at the rate of 24 cents per man per day—30 convicts.

- Breakfast:
  - Rice or grits.
  - White biscuit.
  - Fried bacon.
  - Peas or beans (left-overs).
  - Molasses.
  - Coffee, with sugar or molasses.
- Dinner:
  - Stewed beans or peas, or turnips, or cabbage.
  - Boiled potatoes (white or yams).
  - Boiled bacon.
  - Corn bread.
  - Fresh green vegetables occasionally.
  - (Fresh meat or fish on Sunday when location of camp permits.)
- Supper:
  - Same as breakfast.

On the basis of 45 men to each camp the county ,which paid directly for the food would save $73.50 per month and $882 per year, and could if it desired expend this sum in improving the camp.

In all of the foregoing diet tables there is a striking similarity in the character of the food, but except in a few instances quantities are not given, because accurate detailed information could not be obtained. An intensive dietary study to determine the fuel value of the food actually consumed and the amounts of the food constituents, while of great interest, was beyond the scope of this investigation.

Most of the diets would be improved by the addition of a few inexpensive food materials, such as vinegar, pickles, stewed dried fruits and uncooked green vegetables from time to time as opportunity affords.

Vinegar, for beans and certain vegetables, and pickles are actually craved by many of the negro convicts. While these materials add little, if any, fuel value to the food, they contain certain acid substances of which the body may be in need. In cases where they would add greatly to the satisfaction of the men there can be no reason for not providing them.

Stewed dried fruits, cooked unripe green fruits stewed with sugar, and fresh fruits are a valuable part of any diet. They are pleasing to the taste, add variety, and contain important mineral salts. They may be used in the place of desserts, and should be served daily in some form.

Fresh uncooked green vegetables, such as cabbage, onions, radishes, tomatoes, and the like, form healthful additions to the diet and should be served whenever practicable. It is very essential, however, that they should be washed thoroughly in clean water and not come into contact with dirty hands or filth before being served.

DIET TABLES FOR CONVICT CAMPS.

The following diet tables (18 to 25) have been designed for the purpose of meeting the peculiar requirements of convict camps so far as it is possible to do so. It is believed that these tables are composed of the cheapest food materials that can properly be used in the feeding of convicts, and that the amounts and proportions are such as to insure a well-balanced diet of sufficient food value to maintain a man at hard muscular labor. The food requirements of individuals differ considerably and are also influenced markedly by the amount of hard labor actually performed. It is not to be expected that men on yard work about the camp will require the same amount of food as those engaged in pick and shovel work on the road. Actual experience alone can determine the exact requirements of the camp as a whole.

These tables, as well as the entire discussion pertaining to the subject of food, have been approved by the Office of Home Economics of this department, whose cooperation was sought and whose helpful suggestions have been much appreciated.

TABLE 18.—*Diet without fresh meat.*

[Ration, 17.4 cents.]

Foodstuff.	Ounces.	Proteins.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
White flour (or Graham or whole-wheat flour)	8	1.064	0.120	5.816	$0.04	$0.02
Corn meal	8	.736	.152	6.032	.025	.013
Salt fat pork (plates, backs, bellies.)	8	.592	5.320	....	.12	.06
Navy beans	4	.900	.072	2.384	.06	.015
Potatoes (Irish, sweet, or yams)	16	.288	.016	2.350	.015	.015
Salt codfish	5	.950	.020	....	.09	.03
Dried fruit	1 3/10	.027	....	.933	.12	.009
Sugar	½	....	....	.500	.06	.002
Molasses	2	....	....	1.40	.05	.006
Coffee (1 cup)	⅖	....	....	....	.16	.004
Solids	53⅕	4.557	5.700	19.415	....	.174
Calories	....	524	1,412	2,212	....	....

Total calories 4,178.

Nutritive ratio, 1:6.9.

Ratio fat to carbohydrate, 1:1.5.

Breakfast:
- White or Graham biscuit.
- Fried pork, 4 ounces.
- Molasses, 2 ounces.
- Sugar, one-half ounce, with coffee.
- Coffee, 1 cup.

Dinner:
- Corn bread (from corn meal, 8 ounces.)
- Stewed beans (from dried beans, 4 ounces.)
- Boiled salt pork, 4 ounces (boiled with beans.)

Supper:
- Stewed codfish (milk sauce.)[1]
- Boiled potatoes, 16 ounces.
- Stewed fruit.
- White or Graham biscuit.

Fresh green vegetables or fruits, in season, cooked or uncooked, should be added to this diet; also pickles in reasonable amounts.

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[1] To prepare a milk sauce for codfish and for moistening potatoes: Add 1 ounce condensed milk to 1 ounce water. Season with salt and pepper. Heat and thicken slightly with a little flour dissolved in cold water. Add a little finely chopped pickle and pour over fish. Extra cost=⅝ cent.

TABLE 19.—*Diet without fresh meat.*

[Ration, 16.3 cents.]

Foodstuff.	Ounces.	Proteins.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
White flour (or Graham or whole-wheat flour)	8	1.064	0.120	5.816	$0.04	$0.02
Corn meal	8	.736	.152	6.032	.025	.013
Oatmeal (or hominy grits)	2	.322	.144	1.350	.04	.005
Dried peas	4	.984	.040	2.480	.06	.015
Salt fat pork (plates, back, bellies)	8	.592	5.320		.12	.06
Potatoes	12	.216	.012	1.764	.015	.012
Onions	1	.014	.003	.089	.02	.001
Salt fish (herring, mackerel)	5	1.025	.440		.05	.016
Dried fruit	$1\frac{3}{10}$	.027		.933	.12	.009
Sugar	$\frac{1}{2}$			.500	.06	.002
Molasses	2			1.40	.05	.006
Coffee	$\frac{2}{5}$				.16	.004
Solids	$52\frac{1}{5}$	4.980	6.231	20.364		.163
Calories		581	1,569	2,394		

Total calories, 4,544.

Nutritive ratio, 1:6.8.

Ratio fat to carbohydrate, 1:1.5.

Breakfast:
- White or Graham biscuit.
- Oatmeal mush or grits.
- Fried pork, 4 ounces.
- Sirup, 2 ounces.
- Sugar, one-half ounce, with coffee.
- Coffee (1 cup), two-fifths ounce.

Dinner:
- Corn bread (from corn meal), 8 ounces.
- Stewed peas (from dried peas), 4 ounces.
- Boiled salt pork, 4 ounces (boiled with peas).

Supper:
- Broiled salt fish.
- Lyonnaise potatoes.[1]
- Stewed fruit.
- White or Graham biscuit.

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[1] Lyonnaise potatoes: Boil potatoes until soft. Peel, slice crosswise. Slice 1 ounce onion to each ration. Brown in fat in frying fan. Add to potatoes. Season with salt, pepper, and enough fat to moisten. Bake in pan in oven 30 minutes.

TABLE 20.—*Diet without fresh meat.*

[Ration, 15.4 cents.]

Foodstuff.	Ounces.	Protein.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
White flour (or Graham or whole-wheat flour)	8	1.064	0.120	5.816	$0.04	$0.02
Corn meal	8	.736	.152	6.032	.025	.013
Navy beans	4	.900	.072	2.384	.06	.015
Salt fat pork	8	.592	5.320		.12	.06
Macaroni	2.4	.322	.022	1.778	.10	.002
Cheese	1.5	.314	.015	.064	.18	.009
Cabbage or turnips or other fresh vegetables	12	.168	.024	.576	.01	.008
Dried fruit	1.3	.027		.933	.12	.009
Sugar	.5			.500	.06	.002
Molasses	4			2.800	.05	.012
Coffee	.4				.16	.004
Solids	50.1	4.123	5.725	20.883		.154
Calories		467	1,442	2,394		

Total calories, 4,303.

Nutritive ratio, 1:8.

Ratio fat to carbohydrate, 1:1.6.

Breakfast:
- Hot wheat cakes (see recipe No. 7).
- Fried pork, 4 ounces.
- Molasses, 2 ounces.
- Sugar, one-half ounce, with coffee.
- Coffee (1 cup), two-fifths ounce.

Dinner:
- Baked beans, 4 ounces.
- Salt fat pork, 4 ounces, baked with beans.
- Corn bread (from 8 ounces corn meal).

Supper:
- Baked macaroni and cheese (see recipe No. 30).
- Cabbage, or turnip, or other vegetable, 12 ounces.
- Stewed fruit.
- White or Graham biscuit.

Serve pickles with beans and vinegar with cabbage.

TABLE 21.—*Diet without fresh meat.*

[Ration, 19 cents.]

Foodstuff.	Ounces.	Protein.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
White flour (or Graham or whole-wheat flour)	8	1.064	0.120	5.816	$0.04	$0.02
Corn meal (or mush)	4	.368	.76	3.016	.025	.007
Condensed milk	1	.096	.093	1.120	.10	.007
Oleomargarine or fat	1	....	.940	.940	.12	.008
Rice	2	.16	.006	1.580	.06	.007
Onions	1	.014	.003	.089	.02	.001
Potatoes	24	.432	.024	3.525	.015	.023
Cheese	3	.864	1.077	.009	.18	.034
Eggs	4	.838	1.104	.123	[a] .24	.04
Salt fish	5	1.025	.440	1.580	.05	.016
Dried fruit	1 3/10	.027	....	.933	.12	.009
Sugar	1/2	....	....	.500	.06	.002
Molasses	4	....	....	2.80	.05	.012
Coffee	3/5	....	....	....	....	.004
Solids	57 1/5	4.883	4.567	22.031	....	.190
Calories	....	559	1,129	2,508	....	....

[a] Dozen.

Total calories, 4,206.

Nutritive ratio, 1: 6.5.

Ratio fat to carbohydrate, 1:2.2.

Breakfast:

Corn-meal mush (from 4 ounces corn meal) (see recipe No. 3).

Fried potatoes, 8 ounces.[1]

White or Graham biscuits.

Molasses, 4 ounces.

Sugar, one-half ounce, with coffee.

Coffee (1 cup), two-fifths ounce.

Dinner:

Cheese, 3 ounces, } with bread, as sandwiches.
Fried eggs (2) }

Fried rice and onions (see recipe No. 32).

Supper:

Broiled salt fish.

Potatoes, mashed, 16 ounces.[2]

Stewed fruit.

White or Graham biscuits.

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[1] Fried potatoes: Boil until soft. Peel, slice crosswise. Season with salt, adding one-half ounce oleomargarine or grease to each ration. Spread over bottom of well-greased bake pan to depth of 2 inches and bake in hot oven 30 minutes.

[2] Mashed potatoes: Boil until soft. Peel. Mash well. Add one-half ounce oleomargarine or grease and 1 ounce condensed milk to each ration. Season with salt. Mix thoroughly. Serve hot.

TABLE 22.—*Diet without fresh meat.*

[Rations 18.3 cents.]

Foodstuff.	Ounces.	Proteins.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
White flour (or Graham or whole-wheat flour)	8	1.064	0.120	5.816	$0.04	$0.02
Corn meal	8	.736	.152	6.032	.025	.013
Hominy (or oatmeal)	2	.166	.012	1.580	.03	.004
Salt fat pork	8	.592	5.320		.12	.06
Dried peas	4	.984	.040	2.480	.06	.015
Potatoes	16	.288	.016	2.350	.015	.015
Onions	1	.014	.003	.089	.02	.001
Cheese	3	.864	1.077	.009	.18	.034
Dried fruit	1 3/10	.027		.933	.12	.009
Sugar	1/2			.500	.06	.002
Molasses	2			1.40	.05	.006
Vinegar	1					
Coffee	2/5				.16	.004
Solids	54 1/5	4.735	5.740	21.189		.183
Calories		536	1,442	2,394		

Total calories, 4,372.

Nutritive ratio, 1:7.1

Ratio fat to carbohydrate, 1:1.6

Breakfast:

White or Graham biscuit.
Hominy grits (boiled or fried).
Fried salt pork, 3 ounces.
Molasses, 2 ounces.
Sugar, one-half ounce with coffee.
Coffee, two-fifths ounce.

Dinner:

Stewed peas.
Corn bread.
Salt fat pork, 4 ounces (stewed with peas).

Supper:

Potatoes, 16 ounces.
Onions, 1 ounce.
Vinegar, 1 ounce.
Water, 1 ounce.
Bacon, 1 ounce.
} Potato salad.[1]
Cheese, 3 ounces.
Stewed fruit.
White or Graham biscuit.

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[1] Potato salad: Boil potatoes until well done. Peel. Cut into thin slices. Cut onions into small pieces. Place onions and potatoes together in large dish. Cut bacon into small squares, fry until brown, and while still hot, dash over the potato. Add the vinegar and water. Mix well. Pepper and salt to taste and allow to stand 2 hours before serving.

TABLE 23.—*Diet without fresh meat.*

[Ration 19.2 cents.]

Foodstuff.	Ounces.	Proteins.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
White flour (or Graham or whole-wheat flour)	16	2.128	0.240	11.632	$0.04	$0.04
Oatmeal, hominy, or corn meal	2	.166	.012	1.580	.03	.004
Kidney beans, or navy beans	4	.900	.072	2.384	.06	.015
Salt fat pork	8	.592	5.320	....	.12	.06
Cheese	3	.864	1.077	.009	.18	.034
Onions	2	.028	.006	.089	.02	.002
Cabbage, or other vegetable except potatoes.	13	.182	.026	.624	.01	.008
Potatoes	8	.144	.008	1.175	.015	.008
Dried fruit	$1\frac{3}{10}$	.027	....	.933	.12	.009
Sugar	$\frac{1}{2}$	....	....	.500	.06	.002
Molasses	2	....	....	1.40	.05	.006
Coffee	$\frac{2}{5}$	....	....	....	.16	.004
Solids	$62\frac{1}{5}$	5.031	6.521	19.326	....	.192
Calories	....	570	1,645	2,166	....	....

Total calories, 4,381.

Nutritive ratio, 1:6.6.

Ratio fat to carbohydrate, 1:1.3.

Breakfast:

White or Graham biscuit.
Oatmeal, hominy, or corn meal (boiled or fried).
Fried pork, 4 ounces.
Molasses, 2 ounces.
Sugar, one-half ounce with coffee.
Coffee (1 cup), two-fifths ounce.

Dinner:

Boiled cabbage, or other vegetable, 13 ounces.
Boiled salt pork, 4 ounces (cooked with vegetables).
White or Graham biscuit.

Supper:

Dry stewed beans, mashed, 4 ounces.
Grated cheese, 3 ounces.
Bread crumbs, 3 ounces.
Grated onion, 2 ounces.
} Mix together, roll into loaf. Bake in oven.
Baked potatoes, 8 ounces.
Stewed fruit.
White or Graham biscuit.

TABLE 24.—*Diet with fresh meat.*

[Ration, 21 cents.]

Foodstuff.	Ounces.	Protein.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
Fresh meat (as purchased)	14	2	1.320	....	$0.10	$0.088
White flour (or Graham or whole-wheat flour)	16	2.128	.240	11.632	.04	.04
Rice	2	.16	.006	1.580	.06	.007
Hominy or oatmeal or corn meal	2	.166	.012	1.580	.03	.004
Potatoes	16	.288	.016	2.350	.015	.015
Turnips	1	.009	.001	.057	.02	.001
Carrots	1	.011	.004	.093	.02	.001
Onions	3	.042	.009	.267	.02	.003
Salt fat pork	4	.296	2.660	....	.12	.03
Dried fruit	1 3/10	.027	....	.933	.12	.009
Sugar	1½	....	....	.500	.06	.002
Molasses	4	....	....	2.80	.05	.006
Coffee	⅖	....	....	....	.16	.004
Solids	65⅕	5.127	4.268	21.792	....	.21
Calories	....	570	1,063	2,485	....	....

Total calories, 4,118.

Nutritive ratio, 1:6.

Ratio fat to carbohydrate, 1:2.3.

Breakfast:
- Hominy, oatmeal, or corn-meal mush (from 2 ounces meal).
- Fried salt pork, 4 ounces.
- White or Graham bread or biscuit.
- Molasses, 2 ounces.
- Sugar, one-half ounce with coffee.
- Coffee, two-fifths ounce.

Dinner:
- Meat stew—
  - 14 ounces meat.
  - 16 ounces potato.
  - 1 ounce turnips.
  - 1 ounce carrots.
  - 1 ounce onions.
- White or Graham bread or biscuit.

Supper:
- Boiled rice (from 2 ounces rice).
- Molasses, 2 ounces.
- White or Graham bread or biscuit.
- Stewed fruit.

TABLE 25.—*Diet with corned beef or fresh fish.*

[Ration, 19.5 cents.]

Foodstuff.	Ounces.	Protein.	Fats.	Carbohydrates.	Cost per pound (estimated).	Cost per ration (estimated).
		Ounces.	*Ounces.*	*Ounces.*		
Fresh fish (or corned beef, 12 ounces)	12	1.533	3.612		$0.10	$0.075
White flour (or Graham or whole-wheat flour)	16	2.128	.240	11.620	.04	.04
Hominy, oatmeal, or corn meal	2	.166	.012	1.580	.03	.004
Potatoes	16	.288	.016	2.350	.015	.015
Macaroni	3	.402	.027	2.223	.10	.02
Condensed milk	2	.192	.186	.224	.10	.013
Oleomargarine or fat	½		.470		.12	.004
Onions	3	.042	.009	.267	.02	.003
Dried fruit	1 3/10	.027		.933	.12	.009
Sugar	½			.500	.06	.002
Molasses	2			1.40	.05	.006
Coffee	2/5				.16	.004
Solids	58 7/10	4.778	4.572	21.097		.195
Calories		547	1,163	2,394		

Total calories, 4,104.

Nutritive ratio, 1:6.5.

Ratio fat to carbohydrate, 1:2.

Breakfast:
- Boiled hominy, oatmeal, or corn meal (from 2 ounces dry meal).
- Molasses, 2 ounces.
- White or Graham bread or biscuit.
- Coffee.

Dinner:
- Fresh fish, 12 ounces.
- Boiled potatoes.
- Boiled onions.
- White or Graham bread or biscuit.

Or corned-beef hash—
- Corned beef.
- Potatoes.
- Onions.
- White or Graham bread or biscuit.

Supper:
- Boiled macaroni.
- Milk sauce (for macaroni).
- Stewed fruit.
- White or Graham bread or biscuit.

GARRISON RATION, UNITED STATES ARMY.

The United States War Department after long experience in the feeding of soldiers has determined accurately the kinds and quantities of food materials believed to be best suited to their needs. Fresh meats are ordinarily issued 7 days in 10 and bacon 3 days. The ration includes practically all of the common foods and admits of many combinations which insure variety. It may, however, be supplemented by fresh vegetables and fruits of all kinds when they can be obtained from a post garden or any other convenient source.

The average garrison ration, consisting of fresh beef, soft bread, beans, potatoes, and onions, dried fruit, butter, sirup, and sugar (or their articles of substitution), weighs 65 ounces and contains about 5.5 ounces of proteins, 3.5 ounces of fats, and 17.3 ounces of carbohydrates, with a total fuel value of 3,536 calories. This is about 600 calories less than are usually recommended for men at continued hard muscular labor, such as the building of roads.

The average cost of the garrison ration is now about 27 cents.

Table 26.—*Garrison ration, United States Army.*

[Issued to troops in garrison, in permanent camp, and during maneuvers.]

Article.	Quantity.	Substitute article.	Quantity.
	Ounces.		*Ounces.*
Beef, fresh	20	Mutton, fresh	20
		Bacon	12
		Canned meat, when impracticable to furnish fresh meat	16
		Hash, corned beef, when impracticable to furnish fresh meat.	16
		Fish, dried	14
		Fish, pickled	18
		Fish, canned	16
		Chicken or turkey, dressed, on national holidays	16
Flour	18	Hard bread, to be ordered issued only when impracticable to use flour or soft bread.	16
		Soft bread	18
		Corn meal	20
Baking powder	.08		
Beans	2.4	Rice	1.6
		Hominy	1.6
Potatoes	20	Potatoes, canned	15
		Onions, in place of an equal quantity of potatoes, but not exceeding 20 per cent of the total issue of potatoes.	
		Tomatoes, canned, in place of an equal quantity of potatoes, but not exceeding 20 per cent of the total issue of potatoes.	
		Other fresh vegetables (not canned) when they can be obtained in the vicinity or transported in a wholesome condition from a distance, in place of an equal quantity of potatoes, but not exceeding 30 per cent of the total issue of potatoes.	
Prunes	1.28	Peaches, dried or evaporated	1.28
		Apples, dried or evaporated	1.28
		Jam, in place of an equal quantity of prunes, but not to exceed 50 per cent of the total issue of prunes.	
Coffee, roasted and ground.	1.12	Coffee, roasted and ground	1.12
		Coffee, green	1.4
		Tea, black or green	.32
Sugar	3.2		
Milk, evaporated, unsweetened.	.5		
Vinegar gill	.16	Pickles, cucumber, in place of an equal quantity of vinegar, but not exceeding 50 per cent of the total issue of vinegar.	
Salt	.64		
Pepper, black	.04		
Cinnamon	.014	Cloves	.014
		Ginger	.014
		Nutmeg	.014
Lard	.64		
Butter	.5	Oleomargarine	.5
Sirup gill	.32		
Flavoring extract, lemon.	.014	Vanilla	.014

The following recipes for the preparation of some of the commonly used foods are taken from the Manual for Army Cooks, War Department Document No. 379. The quantities given are based upon those prescribed in the Army ration and are intended to be used in combination with the other foods in the ration. They may, however, be easily modified to meet any requirements.

1. Milk for breakfast foods. Ingredients used: Two 1-pound cans evaporated milk; 8 ounces sugar. Add a pinch of salt and sufficient water to make 1 gallon. Whip well a few minutes. This recipe is sufficient for about 20 men.

2. Coffee (for 60 men). Coffee is generally served for breakfast and dinner and should always be prepared fresh at least once a day. The following method is suggested:

Breakfast: Put 7½ gallons of water in the boiler and let come to a boil; add 2¼ pounds roasted and ground coffee, and remove from the range immediately. Allow to stand 15 minutes; add one pint of cold water, and allow to stand a few minutes longer before serving.

To sweeten, add 4 or 5 ounces of sugar to each gallon.

Dinner: Allow the grounds to remain in the boiler and add sufficient water to make 7½ gallons; allow to come to a boil and add 3 ounces of coffee, roasted and ground, for each gallon of fresh water used; remove from the range and allow to stand 15 minutes; add a pint of cold water, and allow to stand a few minutes before serving.

Coffee should be made for immediate use only.

3. Corn-meal mush (for 60 men). Ingredients used: Six pounds corn meal; 1½ pounds sugar, if not on table; 1 ounce salt; 4 gallons water.

Allow the water to come to a boil and pour in the corn meal, meanwhile whipping well to prevent prevent lumping. Allow to cook for about 20 minutes, and then allow to stand about the same length of time where it will remain hot.

Place in vegetable dishes and serve hot with fresh or evaporated milk poured over it.

4. Corn-meal mush, fried (for 60 men). Ingredients: Seven pounds corn meal; 4 gallons water; 2 ounces salt; 2 ounces sugar.

Prepare in the same manner as corn-meal mush; pour into a well-greased bake pan to a depth of about 1 inch and allow to cool. When cool cut into pieces about 2 inches square; roll in a flour batter and fry in deep lard. Serve hot with sirup.

This preparation may be improved by dipping each piece in an egg batter before rolling in flour.

5. Oatmeal mush (for 60 men). Ingredients: Five pounds oatmeal; ¼ pound sugar; 1 ounce salt; 6 cans evaporated milk; 3½ gallons water.

Place the water in a boiler and allow it to come to a boil; whip the oatmeal in slowly and allow to boil for five minutes. Let simmer one-half hour and serve with milk and sugar.

6. Hominy, fried (for 60 men). Ingredients used: Six pounds hominy; 4 gallons water; 2 ounces salt.

Place the water in a boiler on the range; when boiling add the hominy and boil from 20 to 30 minutes; remove from the boiler, spread about 1 inch deep in well-greased pans, and allow to cool; cut into pieces about 2 inches square; roll in flour and fry in deep lard. Serve hot with sirup or butter.

7. Buckwheat cakes (for 60 men). Ingredients used: Five pounds buckwheat flour; 5 pounds wheat flour; 2½ pounds molasses, or 2½ pounds sugar; 2 ounces salt; 10 ounces baking powder.

Mix the flour and molasses (or sugar) together, and add sufficient water to make a stiff batter. When about to make the cakes, grease the griddle with a piece of bacon or ham, and add the baking powder to each portion immediately before using. If, for example, one-tenth of the above amount is to be baked at a time, one ounce of the baking powder should be added to each portion.

Serve hot with butter, sirup, or both.

8. Bacon, fried (for 60 men). Ingredients used, 15 pounds bacon.

Cut about five slices to the inch; place in a bake pan and pour boiling water over it, and allow it to stand for five minutes. Drain off all the water and fry on a hot range or in a quick oven, when done, remove from the range and allow to cool slightly before serving.

9. Bacon and cabbage (for 60 men). Ingredients used: 15 pounds bacon, 30 pounds cabbage.

Wash and clean the cabbage; place in boiler with sufficient water to three-fourths cover the cabbage; place the bacon on top of the cabbage; after boiling two hours remove the bacon and allow the cabbage to boil one hour longer. To prevent discoloration the boiler should be ventilated during the process of cooking. Serve hot, the bacon being placed on top of the cabbage.

10. Biscuits (for 60 men). Ingredients: 10 pounds flour; 1¼ pounds fat (lard preferred); 2 ounces sugar; 2 ounces salt; 10 ounces baking powder.

Mix the dry ingredients and sift; work in the lard and mix thoroughly; add sufficient water to make a soft dough; roll out about one-half inch thick; cut out with a biscuit cutter and place in bake pan about one-half inch apart; bake in a hot oven about 10 minutes. Serve hot with butter or sirup.

When using baking powder it is better to use cold water (or milk) and keep in a cool place before baking.

11. Bread, corn (for 60 men). Ingredients used: 5 pounds corn meal; 3 pounds flour; 1½ ounces sugar; 8 ounces fat (lard or drippings); 8 ounces baking powder.

Mix the ingredients and sift; work in the lard and mix thoroughly; add sufficient water to make a soft dough; spread in bake pan to a depth of 2 inches, and bake for about 40 minutes.

12. Stock—for use in soups, stews, gravies, potpies, hash, etc.

Save all the bones that come into the kitchen; do not throw them away until all the nutriment has been extracted as follows: Place the bones in the soup-stock boiler with sufficient cold water to cover them from 4 to 6 inches, and allow them to simmer until all the particles of meat attached to them have become loose. There will probably now be sufficient soup stock in the boiler for immediate use. Trim off the bones, saw or crack them, and place in the boiler again, adding more water if necessary, and leaving the bones in the stock until all the nutriment has been extracted (this will require from six to nine hours). When boiled beef is prepared, more stock may be obtained.

13. Stock (definition). The liquid or jelly obtained by boiling meat, bones, etc., for several hours in water. It is the basis of most soups made in Army kitchens

14. Meat stew.[1]

Cut the meat into small pieces, removing the fat; try out the fat and brown the meat in it. When well browned cover with boiling water, boil for five minutes, and then cook in a lower temperature until the meat is done. If tender, this will require about three hours on the stove. Cut potatoes, turnips, carrots, and onions into small pieces. Add turnips, carrots, onions, pepper and salt during the last hour of cooking, and the potatoes 15 minutes before serving. Thicken with the flour diluted with cold water. Such a stew may also be made of mutton. If veal or pork is used the vegetables may be omitted or simply a little onion used. Sometimes for variety the browning of the meat is dispensed with.

Almost any bones and trimmings may be used for making soup. Chuck, flank, neck, fore shank, hind shank, and clod, are among the cheapest cuts of meat and may be used in making meat stew.

15. Beef, boiled (for 60 men). Ingredients used: 20 pounds beef (shoulder, brisket, plate, flank, shank, or neck).

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[1] U. S. Department of Agriculture, Farmers' Bulletin 391.

Cut into pieces weighing about 5 pounds each; cover with water, preferably hot, in order to seal it and retain the juices, and allow to boil from two to three hours, according to the quality of the beef.

16. Beef, braised (for 60 men). Ingredients used: 22 pounds beef; 1 pound onions; 2 pounds fat, or butter; ½ pound flour.

Dice the beef into 1-inch cubes; place the fat in a bake pan and allow to get hot; then put the beef in, together with the onions; put on the top of range or in a quick oven and stir frequently for about 20 minutes. Sift the dry flour in and allow to cook for about five minutes; add sufficient beef stock to nearly cover the meat and stir frequently. Season with salt and pepper, and allow to cook until well done.

17. Beef fritters (for 60 men). Ingredients used: 10 pounds cooked meat; 5 pounds bread; 2 pounds onions.

Soak the bread and remove the water by squeezing with the hands; grind the meat fine and add to the bread; mince the onions, and mix all together; salt and pepper to taste; mold into cakes of about 3 ounces each; roll in flour and fry in deep grease until brown. Serve hot with tomato sauce or gravy.

18. Tomato sauce (for 60 men). Ingredients used: 6 cans tomatoes; 1 pound onions, chopped; ½ ounce cinnamon; ¼ ounce cloves; 2 ounces salt; 2 ounces sugar; ½ pound butter; ½ pound flour.

Cook all the ingredients except the flour and butter, adding 2 quarts of water. Boil slowly for one and one-half hours. Remove from the range and run through a fine colander or sieve. Replace on the range and put the batter into a frying pan. When it becomes hot add the flour, stir until smooth, and add to the sauce. Excellent for fish, meats, etc.

19. Beef hash (for 60 men). Ingredients used: 15 pounds potatoes; 2 pounds onions; 15 pounds meat scraps, etc.; 6 quarts beef stock.

Chop the whole fine and add the beef stock until the mixture is of the consistency of ordinary mush. Place about 3 inches deep in a well-greased pan; smooth the top evenly with the hand and grease slightly; bake in a medium oven for one and one-half hours.

Scraps of beef or pork, or a mixture of both, or corned beef may be used for making hash.

In hot weather, or when the ingredients have been held over for some time, the hash should be spread not more than 2 inches deep in a pan and first placed in a quick oven until the hash is thoroughly heated through—say 20 minutes. Then the temperature may be reduced until the cooking is done.

20. Beef, pot roast (for 60 men). Ingredients used: 22 pounds beef; 2 pounds onions; ½ pint vinegar.

Cut the beef into pieces weighing about 5 pounds each; place in a large Dutch oven or camp kettle, with cover, season well, add onions and vinegar, and place in a hot oven for about 20 minutes; then reduce the temperature and cook slowly until well done. The meat should be turned three or four times while cooking. When done, remove from the kettle and slice; make a thick gravy in the same pot, place the meat on the platters, and pour the gravy over it.

Left-overs from this recipe may be used in hash, potpies, etc.

21. Beef potpie (for 60 men). 20 pounds beef; — gallons stock.

Cut the beef into small pieces, fry slightly in a small amount of grease, and add sufficient stock, or water, to cover the meat. Allow to simmer until the meat will nearly fall apart, then season with salt, pepper, and onions. Thicken slightly with flour batter, and place in a dish or pan at least 2 inches deep, with a crust or biscuits spread over it. Place in the oven and brown in the same manner as ordinary pies.

22. Potato and beef pie (for 60 men). Ingredients used: 20 pounds potatoes, boiled and mashed; 12 pounds beef, diced· 3 pounds onions, browned.

Season the mashed potato with pepper and salt, put a layer of potatoes about half an inch thick into a vegetable dish, roll the beef in flour, season with salt and pepper, and fry brown in a little fat; brown the onions and mix with the beef; add a little beef stock and cook for about 15 minutes; place a thin layer of chopped onions inside of the layer of potatoes in the vegetable dish; fill up with the mixture of meat. Place a layer of mashed potatoes on the top and round off nicely. Grease well, and bake until nicely browned. Serve hot in the dish in which baked.

23. Beef hearts stewed (for 60 men). Ingredients used: 18 pounds beef hearts; 1½ quarts tomatoes; 1 pound onions, fried; 1 pound flour; 3 gallons beef stock.

Make a gravy of the flour and beef stock and put on the range; meanwhile split the hearts in two and wash them thoroughly, and when the gravy comes to a boil put them in. Cook in the oven or on top of the range until done. Slice and serve on a platter with the gravy poured over them. Season with cloves, allspice, bay leaves, a little garlic, pepper and salt, while cooking.

24. Liver and bacon in gravy (for 60 men). Ingredients used: 15 pounds liver; 8 pounds bacon; 6 pounds onions, browned; 2 pounds flour; 4 gallons stock.

Slice the bacon thin and wash in boiling hot water, not allowing it to remain in the water more than five minutes; fry quickly until medium well done. Roll the slices of liver in flour, and fry in the fat after frying the bacon; add the liver and bacon to the stock, and bring to a boil; thicken slightly with a flour batter, adding salt and onions to taste. Serve hot.

25. Codfish, salt, boiled (for 60 men). Ingredients used: 20 pounds salt codfish.

Break the fish into pieces weighing about 2 ounces each; allow to boil for 15 minutes to remove the salt; change the water and boil until done, ordinarily about 30 minutes. Serve hot with cream sauce.

26. Cream sauce for codfish (for 60 men). Ingredients used: 1 pound fat; four 12-ounce cans evaporated milk; ½ pound onions, minced; ½ pound pickles, minced (if convenient).

Thicken 1 gallon of boiling water with a flour batter, and season well with pepper and salt; let come to a boil and add the fat, milk, onion, and pickles; whip well and spread over the fish on the platter.

27. Codfish cakes (for 60 men). Ingredients used: 10 pounds salt codfish; 10 pounds potatoes; 12 eggs.

If whole cod is used, soak, boil, remove the bones, and pass through a meat chopper; mix with the potatoes and eggs, season to taste with pepper and salt, and mold into cakes weighing about 3 ounces each. Roll in cracker crumbs or flour and fry in deep fat. They may be served with tomato gravy.

28. Potatoes, mashed (for 60 men). Ingredients used: 22 pounds potatoes.

Peel, wash in cold water, and boil until thoroughly done. Strain, salt, and mash well. Instead of the milk and butter often used in this preparation, carefully strained beef stock and fat may be used. Whip well with a basting spoon for about five minutes and serve hot.

29. Potatoes, Lyonnaise (for 60 men). Ingredients used: 22 pounds potatoes; 2 pounds onions.

Wash the potatoes and boil them until they may be easily pierced with a fork; peel and slice crosswise; wash and slice the onions; fry brown and add to the potatoes. Season with pepper and salt, adding sufficient fat to moisten, and spread about 2 inches deep in the bottom of a well-greased pan. Bake about 30 minutes in a quick oven.

30. Macaroni and cheese (for 60 men). Ingredients used: 6 pounds macaroni; 2 pounds cheese, diced.

Add the macaroni to 4 gallons of boiling water, salted to taste; allow to boil about 20 minutes, but not until it becomes flabby, and strain the water off; spread about one-third of the macaroni in the bottom of a well-greased bake pan; then one-third of the diced cheese on the macaroni; continue the alternate layers until all is in the bake pan. Bake in the oven about 30 minutes and serve hot.

31. Rice boiled (for 60 men). Ingredients used: 5 pounds rice; 3 gallons water.

When the water comes to a boil add the rice. When the rice may be mashed with the fingers pour into a colander and drain well, after which each grain should be whole and separate.

32. Rice, fried (for 60 men). Ingredients used: 5 pounds rice; 2 pounds fat; 1 pound onions, diced.

Boil the rice as in the preceding recipe; place the fat in a bake pan; set on the range and let come to a smoking temperature; add the onions and let them brown slightly; add the rice and stir continually with a cake turner to prevent burning and to mix the grease with it thoroughly. Rice may be cooked in a hot oven and must be stirred every few minutes. About 15 or 20 minutes are required to fry it.

33. Stewed dried fruit—prunes, apples, peaches, apricots, etc.—(for 60 men). Ingredients used: 5 pounds dried fruit.

After washing the dried fruit place it in a receptacle with about three times its bulk of water, and set on a part of a range where it will keep hot but not boil. After two hours, remove and season to taste with sugar, cinnamon, cloves, or nutmeg, and a little vinegar.

34. Pudding, bread (for 60 men). Ingredients used: 12 pounds bread crusts; 2 pounds dried fruit; 2 pounds sugar; 1 ounce cinnamon; 2 cans evaporated milk; 6 eggs.

Soak the bread in cold water and squeeze out well with the hands; season well with sugar and cinnamon; mix well, and spread about 1 inch in pans; over this spread about 1 inch of stewed fruit; then another layer of the bread, and over the top spread sugar and cinnamon; bake about forty minutes in a medium hot oven. Serve hot or cold with cream and sauce. This makes an excellent dish and gives an opportunity to use all the scraps of bread on hand.

SELECTION OF THE COOKS.

Cooks and waiters chosen from the convict force prepare and serve the food at all camps. Little difficulty is experienced in finding good cooks in almost any group of fifty or more prisoners, and as the men assigned to the kitchen work generally are under less restraint than those working on the roads they accept their duties cheerfully. The larger camps require intelligent men who are reasonably skillful in their work, and for this reason the selection is often made at the penitentiary, the men then being assigned to the camps for the express purpose of cooking. In certain States such men are examined by the prison physicians, who are careful to see that they are not suffering from infectious diseases which would render them dangerous as cooks, and while a bacteriological examination is never made, in order to rule out the possibility of their being disease carriers the prison physicians usually obtain their medical histories and occasionally administer anti-typhoid vaccine. Such careful selection of cooks results in very satisfactory conditions at the camps. The food is well cooked and decently served, the kitchens and messrooms and the cooking and eating utensils, are kept clean and in good condition, and a general feeling of pride and satisfaction prevails. The plainest foods, when properly cooked and decently served in clean surroundings, are valued much more highly than more elaborate articles of food prepared and served in a sloppy manner.

Unfortunately the same care in the selection of the cooks is not used at all camps, and in many cases convicts are sent to the road camps with no physical examinations whatsoever. From this miscellaneous assortment of men, the superintendent of the camp must select his cook and kitchen force, and it is almost inevitable that, at times, he should choose diseased individuals who prove a menace to the health of the entire camp.

Competent physicians always should examine all persons engaged in cooking and handling the food, and particular attention should be directed to the possibility of their being typhoid carriers or sufferers from tuberculosis. Both of these diseases may be transmitted readily in the food, and many cases are on record which show the terrible consequences which may follow the employment of such persons about the food. Individuals who apparently have recovered entirely from a recent attack of typhoid fever, and others who have the disease in a very mild form, may show no physical signs of illness and yet harbor the disease germs in their bodies and be a dangerous source of food contamination. A recent outbreak of 93 cases of typhoid fever was traced to food contaminated during preparation by a woman who had quite recovered from an attack of typhoid fever. It is known that certain persons may harbor the germs in their bodies for years after the disease is over, and this condition can be detected only by proper medical examination.

Personal cleanliness is a matter of the greatest importance in the case of those who come in contact with the food, but this is a somewhat variable condition in convict camps, and depends largely upon the officers in charge of the camp. In many camps the cooks and others employed about the kitchen and dining room are reasonably clean, and water, soap and towels are in evidence, with signs of being used, but at other camps the men and their surroundings are disgustingly dirty and it is useless to inquire when and where they wash.

It should be the duty of every officer in charge of a camp to instruct cooks, helpers, and waiters as to cleanliness of their persons and clothing, and to see that adequate facilities are provided for their cleanliness. The necessity for washing the hands after visiting the toilet is not understood in all cases and should be strongly emphasized.

It would be well if every camp kitchen could have the sign found in some well-managed food factories: "When you leave the room for any purpose, wash your hands before you return to work."

A bath should be taken daily, especially in warm weather.

Cooks, helpers, and waiters should not be permitted to wear their ordinary clothing when at work in the kitchen and dining room. It is a common custom to use the yardmen as waiters during meal hours. These men, after being employed at various tasks of cleaning about the camp, come directly into contact with the food while wearing clothing soiled by all sorts of camp wastes. Large white aprons could be provided at a very slight cost and would aid materially in maintaining the cleanliness of the kitchen force, and in preventing contamination of the food.

It happens not infrequently at the smaller camps that there is no prisoner with a knowledge of cooking, and under such conditions an ignorant, untrained man may be pressed into service. This results usually in a monotonous run of badly cooked food with all its attendant waste and dissatisfaction, and the convicts, badly fed and poorly nourished, fall ready victims to disease and can be worked only at an economic loss.

STOVES AND COOKING EQUIPMENT.

Good stoves are furnished at many camps and the food is prepared in much the same way as in the ordinary household kitchen. Not infrequently, however, the cooking of beans, peas, and vegetables is done in a large iron kettle suspended over an open fire out of doors, and the kitchen stove is thus left free for frying meat and baking. At one camp visited the cooking was done on a sort of wooden tray, about 4 feet square, supported on stakes driven into the ground. The tray was filled with earth which formed a bed upon which the fire was made. This improvised cooking apparatus, shown in Plate XIV, figure 1, was constructed in the open air, and together with the necessary pots and pans, comprised the camp kitchen. It should be stated, however, that a wooden shelter was to be built at some future date to protect the cook from the sun and rain and to provide a shelter for the cooking utensils.

METHOD OF STORING AND PRESERVING FOOD SUPPLIES.

A storeroom for the keeping of food supplies is provided at all camps, and is located either under the same roof as the kitchen and dining room or in a separate building or tent. Whatever its location, it is usually so arranged that it may be kept securely locked. The key is kept by one of the camp officials, and access to the food supplies by the convict cook or other inmates is permitted only when absolutely necessary. As a rule the foodstuffs are kept in well-covered barrels and boxes and appear to be in good condition. The quantities purchased are generally used within a month, and it is probable that waste due to improper storage is very slight.

Though it is highly important that storerooms be kept clean, it is also essential that they be as dry as possible, and for this reason soap and water should be used sparingly. Dishes of unslaked lime placed within the room are useful in absorbing moisture and insuring a dry atmosphere; while fresh air, sunshine, and whitewash are important aids to cleanliness.

Flour is best kept in warm, dry, well-lighted rooms, carefully protected from dust. Cornmeal does nor keep as well as flour and should be bought in quantities which can be used without long storage. Breakfast cereals, when bought in bulk, should be kept in tight receptacles in a cool, dry place. Rice, macaroni, and other dry foodstuffs of similar character, and also raisins, currants, and evaporated and dried fruits are best kept in covered cans or jars. Sugar may be well kept in tin boxes, but salt should be stored in wooden receptacles. Glass preserve jars are convenient for small quantities of almost any kind of food.

At camps in which perishable foodstuffs are a part of the daily fare, ice boxes or refrigerators should be provided if the location is such that ice can be obtained. In this connection it should be remembered that, as freezing does not kill all disease germs, ice is not always free from dangerous contamination, and no food should be brought into direct contact with it unless its purity is above suspicion. If the food is to be kept in good condition the interior of the ice box should be wiped each day with a dry cloth, and once a week all ice and food should be removed so that the sides, shelves, and drain may be thoroughly scalded. The cleansing of the drain is exceedingly important for if it is allowed to become clogged the water is not carried off fast enough and little pools are formed in which bacteria may breed in great numbers. Under these conditions food will keep only a very short time.

Since in many of the southern camps the use of ice is impracticable, the food must be of such character as to require no ice for its preservation. Under these conditions screened cupboards may be used for the preservation of cooked foods during short periods. In these receptacles the food is protected from flies, but warm food furnishes an excellent medium for the growth of bacteria, and ordinarily should be kept only from one meal to the next.

In some of the Western States where the climate is very dry, meats may be suspended from hooks in small screened inclosures open to the sun and air on every side (see Pl. XIV, fig. 2). Under these conditions the surfaces of the meat rapidly dry and harden and the interior will remain in a state of good preservation for a considerable length of time.

At one of the camps visited, the contrivance for keeping food cool was based on the principle that water in evaporating draws heat from surrounding objects. A wooden box about 2 feet square and 4 feet high was placed on end and fitted with shelves for the food. The top end of the box was covered with several layers of burlap, and a burlap curtain was suspended over the one open side. An old dish pan, in the bottom of which a few small holes had been punched, was placed on top of the box and in this way the burlap on the top and side was supplied with just enough water to keep it saturated. Food was kept in this box at a temperature considerably lower than that of the outside air.

FOOD POISONING.

Food poisoning may be caused by foods which have been kept too long before being eaten, or which have not been properly cooled and stored. The poison results from certain bacteria of one or more kinds accidentally present in the food, which are not killed by the heat of cooking or which are conveyed to the food (by dirty hands, for instance) after it is cooked. The contamination usually is such that it can not be detected by the sense of taste. While food poisoning has been known to occur in many different kinds of food, those most commonly mentioned are soft cooked vegetables—especially if put away warm—soups, meat pies and similar dishes, milk, fish, meat, baked beans and ice cream.

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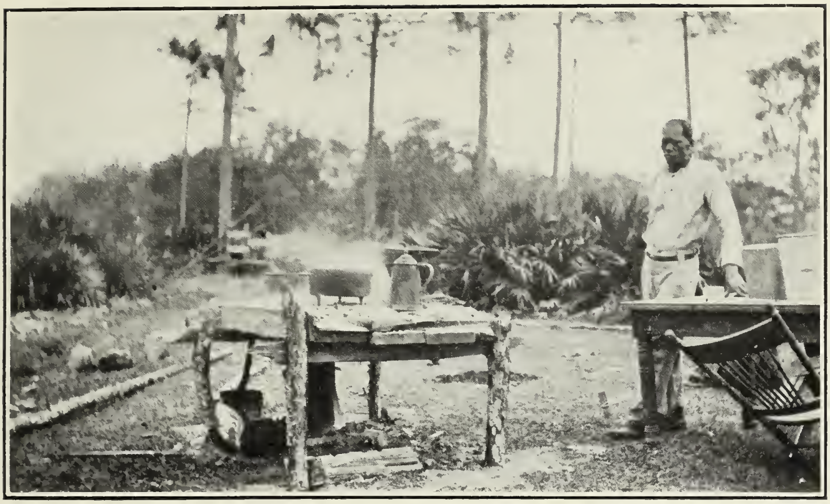

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FIG. 1.—A PRIMITIVE COOKING ARRANGEMENT.

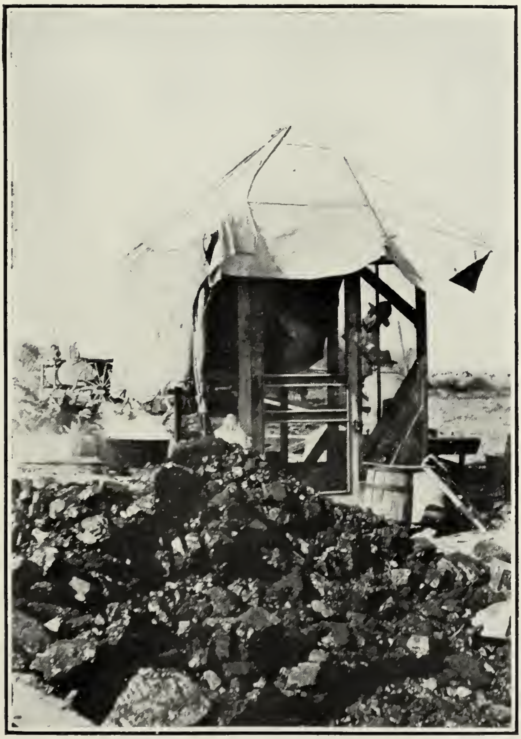

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FIG. 2.—SCREENED ENCLOSURE FOR KEEPING MEATS.

APPENDIX.

A DIGEST OF STATE LAWS RELATING TO THE USE OF CONVICT LABOR FOR ROAD WORK.

By L. E. Boykin, *Assistant in Road Economic Investigations, Division of Road Economics.*

In the last few years there has been a notable increase in the number of States which permit the use of prison labor in highway work or in the preparation of road materials. During the year 1915 26 of the 44 State legislatures which were in session enacted new legislation bearing on the subject. At the present time all but two States have laws authorizing such use. There follows a brief digest of such general laws as were in force in the several States January 1, 1916. Numerous special laws also exist in many States, but they have only a local or special application, and no attempt has been made to include their provisions in this digest.

Alabama.

State.—An amendment to the constitution was voted, August, 1907, authorizing the legislature to appropriate part or all of the net proceeds from the State convict fund to the construction, repair, and maintenance of public roads. In pursuance of the authority thus conferred the legislature, by act of April 5, 1911, appropriated from said State convict fund the sum of $154,000 annually to be apportioned, after making the deduction allowed by law for the salaries and expenses of the State highway commission, equally among the several counties of the State.

Counties.—The convicts of any county or municipality may be worked upon the public roads, bridges, or ferries of the county, or in quarries, gravel pits, or any plant used for the production of road materials, under the direction of the court of county commissioners or board of revenue; or said convicts may be hired to or from another county or from the State. No female convict shall be so worked, but may cook and prepare meals for road crews. (Acts 1915, No. 505.)

Courts of county commissioners, boards of revenue, or other like governing bodies of the several counties, may work county and State convicts on the public roads and bridges of their respective counties; and they may hire their county convicts to, hire from, or exchange with, other counties, under such terms as may be mutually agreed upon for the purpose of building and maintaining the public roads. Said governing bodies of the several counties may contract with the State convict department for State convicts to be used for a like purpose, under such regulations as may be prescribed by the said State convict department. They may also purchase necessary cells, tents, equipment, and clothing, hire sufficient guards, and provide proper medical treatment. Said governing bodies may pay all expenses incident to employing such convicts out of any funds available for road and bridge work in their respective counties. (Acts 1915, No. 580.)

Arizona.

State.—The State board of control may cause persons sentenced to imprisonment in the State prison to work upon the construction, repair, or maintenance of State roads, highways, and bridges in the several counties, on request of the county supervisors thereof, and in conformity to the directions and specifications of the State engineer. When the board of control shall decide so to work such convicts, the secretary of said board shall notify the superintendent of the State prison to furnish such number of men as the board may direct and cause them to be removed to the place or places where such work is to be done. All implements, tools, machinery, supplies of every kind, all animals necessary for the prosecution of such work, and suitable shelter for men and animals shall be purchased and provided by said board of control. The State engineer may establish and maintain camps or enclosures for the men so employed and, with the approval of the board of control, make and provide suitable methods of enforcing rules and regulations for governing the men while so employed. When the work on which such prisoners are employed is completed, or for any other reason deemed sufficient by said board of control, the State engineer shall cause such prisoners to be returned to the State prison or to other place of employment, together with all equipment, supplies, machinery, tools, and implements. The cost of transporting convicts so employed, and necessary guards, to and from the State prison, or from one place to another, together with all other expenses necessarily incurred in or about the employment of such convicts and the carrying on of any such work shall be payable as follows: That portion equaling the maintenance cost at the State prison for the number of prisoners employed shall be paid from the prison maintenance fund and the remainder from the State road-tax fund. All claims therefor shall be in such written form as may be prescribed by the State board of control, approved in writing by the State engineer, and audited by the State auditor. Payments shall be by warrants drawn on the State treasurer and countersigned by the governor. Counties availing themselves of this act shall not, during the same fiscal year, be entitled to any portion of the State road-tax fund, except such as would be a proper engineering charge. (R. S., 193, secs., 5141–5148; Laws 1913, third sp. sess., as amended; Laws 1915, ch. 35.)

Counties.—The keepers of the jails of the several counties, when any person shall be sentenced to hard labor therein, and any mode of labor shall be provided, shall keep such prisoners constantly employed. Such labor may be performed inside or outside the walls of such jails, and, on discharge of the prisoner, shall be reported to the board of supervisors. Any such prisoner who shall be so employed when sentenced to pay a fine, and imprisoned in default of such payment, shall be allowed the sum of $1 for each day he shall so work, which shall be credited on such fine (R. S., 1913; secs. 1482, 1486.)

ARKANSAS.

State.—The superintendent of the penitentiary may, in his judgment, order the roads leading to and in the neighborhood of the several camps now or hereafter occupied by the inmates of such penitentiary, worked and repaired by the labor of such convicts, provided that no such convict shall be required so to work for a greater number of days than now allowed by law for regular road hands. (Kirby's Digest, 1904; sec. 5873).

The department of State lands, highways, and improvements shall employ as many State convicts on the public roads as may not be otherwise employed by the penitentiary authorities. Convicts so worked shall be under the care and management of wardens and other officers named by the penitentiary authorities, but said department shall determine the work to be done, and the time, place, and manner of doing it. Salaries of wardens and cost of clothing of such convicts while so employed shall be paid by the State, and the cost of feeding and housing them shall be paid by the county or improvement district where they may be worked. When practicable, the said department of lands, highways, and improvements may engage State or county convicts available in preparing road materials at quarries or elsewhere, and the expenses of such work shall be charged to the State or to the county or district receiving such materials. (Act 302, 1913, as amended by Act 338, 1915.)

Counties.—If the county court or judge thereof shall be unable to make a satisfactory contract for the working of the convicts of the county, said court or judge thereof may order the prisoners on the roads, bridges, levees, or other public improvements of the county, under such rules and regulations as such court or judge may prescribe. Said court or judge shall appoint a superintendent to have charge of said prisoners, and he may employ such guards or adopt such means to prevent escape as may be necessary. The county court, at its annual meeting for making appropriations, shall make necessary appropriations to carry out the purposes of this act, but not more than $10,000 shall be appropriated for any one year. While prisoners are so worked in charge of said superintendent, the sheriff shall feed them and receive regular fees allowed therefor. If any prisoner shall escape, he shall be compelled to work out all costs of his recapture. Commissioners of public roads may supersede such superintendent. (Kirby's Digest, 1904; secs. 1101–1108, 7237–7238.)

Counties of judicial circuit.—The county judges of counties composing any judicial circuit or of any contiguous portion of any judicial circuit may meet and, by unanimous vote, adopt the provisions of this act, whereupon they shall organize by electing a chairman and a secretary from among their number and shall, when so organized, constitute the county convict board for said counties. Said board shall purchase a road-making outfit and necessary equipment for properly caring for the convicts of said counties while worked on the roads therein, an equal portion of the cost thereof to be paid by each of said counties. Each county may furnish such road equipment as it may possess and such board may deem suitable, and be allowed therefor its reasonable market value. Said board shall employ a road foreman who shall have charge of said outfit and equipment and work the convicts of such counties on the public roads thereof. Said board shall meet annually to elect officers and transact other business, and at such other times as may be necessary, and may adopt rules and regulations for the management and discipline of said convicts, including such punishment as may be deemed right and proper for violations thereof. Said board may appoint a road engineer, if it shall deem advisable, the cost thereof to be borne equally by the counties. The road foreman shall work said convicts an equal length of time in each county each year, and shall notify the county judge of each county at least 30 days in advance when he will be in his county, and submit an estimate of supplies that will be needed for said convict gang while at work therein, and the said county judge shall furnish such supplies. The convicts shall be worked on the roads designated by the county judge. The county court shall pay the salary of the foreman and any other paid employees with said convicts while working in that county. Persons imprisoned for nonpayment of a fine and costs may be so worked until same are paid and shall be allowed on same for each day they shall so work 75 cents. Prisoners from cities and towns may also be worked, and prisoners may be hired from other counties. If any prisoner shall escape, or attempt to escape, the time for which he was liable to work shall be doubled. No convict shall be worked over 10 hours per day, and when discharged shall be given $1 in money and, if he has worked six months, a $10 suit of clothes. White convicts shall not be required to sleep or eat with negroes, and females shall not be worked on roads. Felony convicts sentenced to penitentiary for five years may be so worked. Persons held in default of bail, may, at their election, be so worked and shall receive 75 cents per day for labor so performed, to be credited on fine and costs if convicted. Work may be discontinued by said board by a majority vote at any annual meeting. (Acts 1913, No. 306.)

Convict road district.—At the July term of the county court each year the county judges in any two or more contiguous counties may enter into an agreement for the formation of a road and convict district. There may be worked on the roads of such district all prisoners convicted of misdemeanor in justice's courts and whose fines are not paid, and prisoners convicted in the circuit court for misdemeanor or felony. The county courts shall provide for the care and maintenance of all prisoners while working in their respective counties, including guards, wardens, clothing, medical attention, equipment, supplies, stockades, camps, etc., and may pay for same out of any money appropriated for roads and bridges. Prisoners shall not be worked more than 10 hours per day, and such labor shall be valued at 75 cents per day. Males and females and whites and blacks shall be kept separate. Any convict whose conduct is exemplary and services good for six months shall be entitled to a commutation of one month; for one year, two months; for two years, five months; for three years, six months; and for four years, the prisoner sentenced for five years shall be discharged. Prisoners serving two years or more shall on discharge be furnished by the sheriff with $2.50 in money and $12.50 worth of clothing. The county judge, the county clerk, and the sheriff of each county shall constitute a board to prescribe and enforce rules governing work, care, location, and punishment of such convicts. Persons held in default of bail may, at their election, be worked as other convicts and credited with 75 cents each day they shall work. (Acts 1909, No. 207.)

Road improvement district.—Provision may be made in any highway charter (for road improvement district) for working male convicts of any county on the roads thereof. Every charter providing for so working convicts shall also provide for the appointment of overseers, guards, physicians, and other necessary officers and employees. The cost of feeding, clothing, housing, and superintending such convicts shall be charged to the particular district or county where they are worked in proportion to the time they may be used therein. (Acts 1913, No. 302.)

CALIFORNIA.

State.—State prison authorities may use State prisoners in preparing road and bridge-building materials. (Acts 1901, ch. CXII, being S. 1588 of Penal Code, and Acts of 1911, ch. 56.)

The department of engineering may employ State convicts in the construction and maintenance of the State highway system provided for by the "State Highway Act," approved March 22, 1909, and in the construction and maintenance of any other State roads. Upon requisition of said department, the State board of prison directors shall send to the designated place, and at the appointed time, the number of convicts desired. Said department of engineering shall designate and supervise all road work done, but said board of prison directors shall retain full jurisdiction over the discipline and control of such convicts. The expense of transportation, guarding, commissariat, camps, and all other expense incident to such work shall be paid from the respective funds provided for such State road work. Convicts shall not do any work which requires the employment of skilled labor. The said board of prison directors shall adopt a special rule applicable to such convicts, whereby additional good-time allowance may be granted for good conduct and efficient service, but not to exceed one day for each two calendar days that the convict is absent from the prison. (Acts 1915, ch. 124.)

Counties.—Any person convicted of abandonment and nonsupport of a wife, child, or children and sentenced to imprisonment in the county jail may, at direction of the court, be compelled to work on the public roads, or any other public works, in the county. Where such work is performed, the board of supervisors shall order paid to the wife, or the guardian or custodian of such child or children, at the end of each calendar month, not to exceed $1.50 for each day's work so performed. (Acts 1911, ch. 379.)

The boards of supervisors, in their respective counties, may provide that prisoners confined in the county jail on conviction of misdemeanor, shall, under direction of some suitable person to be appointed by the sheriff, work upon the public roads, streets, alleys, highways, or in such other places as may be deemed advisable for the benefit of the county. (Acts 1911, ch. 746.)

COLORADO.

State.—Convicts of the State penitentiary engaged in work outside the walls thereof, and known as "trusty prisoners," who shall comply with the prison rules and perform their work in a creditable manner may, upon the warden's approval, be granted such good time in addition to that allowed by law as the Board of Penitentiary Commissioners may order, not to exceed 10 days in any one calendar month. (Acts 1909, ch. 153.)

Upon the written request of the board of county commissioners of any county, the warden of the State penitentiary shall detail such convicts as in his judgment shall seem proper, not exceeding the number requested, to work upon such public roads of such county, or streets or alleys of any city or incorporated town therein, as shall be designated in said request. Such county shall pay all additional expense of guarding such convicts and shall furnish tools and materials while working on the roads therein; and such expenses shall be met by such city or incorporated town when such work is done on the streets or alleys thereof. (R. S. 1908; sec., 4879.)

The legislature has established the "Santa Fe Trail" highway to extend from a designated point on the northern boundary of New Mexico through Trinidad, Denver, and Fort Collins to a designated point on the northern boundary of Colorado. The construction and maintenance of said road and extensions thereof shall be under control of the Board of Commissioners of the State Penitentiary and the warden of said penitentiary, who shall use therefor the labor of the penitentiary convicts. Supervision of the work shall be under such competent persons as may be selected by said board of penitentiary commissioners. Convicts shall not be worked over eight hours per day. Said board of penitentiary commissioners may adopt rules and regulations providing for granting additional good-time allowance to short-term men and better food for life prisoners, conditioned on good behavior and efficient work. (R. S., 1908; secs., 5855–5859.)

At various times appropriations have been made by the legislature to purchase tools, equipment, supplies, etc., and to pay for extra guards, in building certain specified roads with the labor of State convicts. (Acts 1909, chs. 55, 92, 95; Acts 1911, chs. 54, 56.)

An appropriation was made and authority conferred for working paroled prisoners from the State reformatory, under direction of the State reformatory commissioners and the warden of the Colorado State Reformatory, on the highway following the Arkansas River from Pueblo to Leadville. Such prisoners receive a salary of not to exceed $1 per day and board for each day they shall so work. Necessary road equipment was to be provided from the appropriation made. If a prisoner shall be returned to the reformatory for misconduct he shall forfeit any unpaid balance due on his salary. (Acts 1909, ch. 112.)

Counties.—Persons serving a sentence in any county jail who shall faithfully perform the duties assigned during the term of imprisonment shall be entitled to a deduction from such sentence of two days in each month. Any such prisoner who shall escape, or attempt to escape, shall forfeit all accrued deductions to which he may be entitled. Upon written request of the board of county commissioners, the sheriff shall detail such male prisoners as he may deem proper, not exceeding the number requested, to work on such roads of the county, or such streets and alleys of any city or incorporated town, as may be designated in such request. The county shall pay all additional expenses of guarding such prisoners while so working and furnish necessary tools and materials, but where work is done within the limits of a city or incorporated town such city or town shall pay such additional expenses. Prisoners shall not be used to build a bridge or like structure which requires skilled labor. Prisoners doing work outside the walls of the jail who shall render faithful service and obey the rules prescribed by the sheriff shall be allowed such good time, in addition to that otherwise granted, as the sheriff may order, not to exceed 10 days in one calendar month. (Acts 1911, ch. 184.)

The keepers of said prisons (meaning, no doubt, sheriffs and county jailers) may, with the consent of the county commissioners, cause such convicts under their charge as are capable of hard labor to be employed on any public avenue, street, highway, or other public works, quarries, or mines, in the county in which such prisoners are confined, or in any of the adjoining counties, upon such terms as may be mutually agreed upon. (R. S. 1908, sec. 2022.)

The sheriff of each county shall feed prisoners kept in confinement by him with good and sufficient food; and the county commissioners shall, at expense of the county, supply all things necessary in the performance of said duty. (Acts 1915, ch. 111.)

CONNECTICUT.

Counties.—The county commissioners of any county may, with consent of the sheriff, cause prisoners serving terms in the jail or workhouse thereof to labor upon any bridge, or public highway or property adjacent thereto. (Acts 1915, ch. 180.)

DELAWARE.

Sussex County.—The levy court may employ persons convicted and imprisoned in the county jail, or other places of detention, upon the public roads of the county, or upon the farm of the trustees of the poor, and said court may fix the compensation of such prisoners for all labor so performed, if it shall be deemed wise to pay for such labor. Such compensation may be paid to the dependent members of the families of prisoners. (Acts 1915, ch. 76.)

Kent and Sussex Counties.—Male persons convicted of crimes punishable by imprisonment at hard labor may, in the discretion of the court, be sentenced to labor on the public roads for not to exceed 8 hours a day and for not more than 3 months in any instance. The levy court may employ necessary guards and others, and may also employ a "superintendent of convict gangs," who shall have the same power as a deputy sheriff. If necessary, suitable camps shall be provided by the sheriff with proper provision for feeding the convicts. The cost of maintaining such camps shall be paid by the levy court. Prisoners who become refractory and refuse to work may be placed in solitary confinement and fed on bread and water. (Acts 1913, chs. 272, 273.)

New Castle County.—By act of 1893 the levy court was authorized to secure, by purchase or condemnation, a stone quarry to be worked by convicts sentenced to the workhouse at hard labor. Eight hours constitute a day's work at said workhouse. Prisoners refusing to work, or failing to perform their work satisfactorily, may be placed in solitary confinement by the superintendent of the workhouse and be fed on bread and water. Such work and the care and custody of the prisoners shall be under the management and direction of the superintendent of the workhouse. Supplies for feeding the prisoners shall be purchased by contract let after due advertisement. The levy court shall provide necessary guards and other employees. Commissioners of the jail and workhouse may make rules for the government and operation of the workhouse and all persons connected therewith. Said workhouse shall be properly equipped for breaking stone suitable for road-building purposes, to be divided among the several hundreds of the county making application therefor and upon payment of the transportation charges thereon. Provision is made for disposing of the surplus stone produced. (Acts 1893, ch. 670.)

The levy court may make an agreement with the board of trustees of the New Castle County Workhouse for employing prisoners confined therein in building or repairing any of the public highways of the county. (Acts 1913, ch. 271.)

FLORIDA.

State.—The State prison physician shall examine and grade all State convicts into three grades or classes, to wit: Grade or class one, all able-bodied male negro convicts; grade or class two, women and infirm convicts; grade or class three, all negro convicts who have served ten years or longer and all white male convicts and all negro male convicts not included in classes one and two. Convicts included in grades one and three may be worked on the public roads of counties on application therefor by the county boards of commissioners to the board of commissioners of State institutions. The counties shall, at their expense, guard, feed, clothe, maintain, and give medical attention to all convicts so employed. Convicts so employed shall at all times be under the supervision of the board of commissioners of State institutions, and shall comply with all rules and regulations prescribed by said board and the commissioner of agriculture. All grade one convicts so used shall be paid for at the rate of $10 per month, and grade three prisoners at the rate of $1 per month. Convicts shall not be worked more than 10 hours a day. (Acts 1916, ch. 6915.)

The commissioner of agriculture shall keep a record of the conduct of each prisoner, and, when no charge of misconduct has been sustained against him, the following deductions from his sentence shall be made by the board of commissioners of State institutions: Two days per month off for first year of sentence; 3 days for second year; 4 days for third year; 5 days for fourth year; 6 days for fifth year; 7 days for sixth year; 8 days for seventh year; 9 days for eighth year; 10 days for ninth year; and 15 days per month off for the tenth year and all succeeding years. Accrued commutation shall be forfeited for mutinous conduct or for escape or attempted escape. (Acts 1915, ch. 6917.)

Counties.—Boards of county commissioners may employ all persons in the jails of their respective counties, under sentence for crime, at labor upon the streets of incorporated cities and towns, or upon roads, bridges, and public works of the county; or the said boards may, in their discretion, lease such convicts to be kept and worked either within the county or in any other county in the State. No female, or physically disabled convict, shall be so worked. Said convicts shall be kept and worked under such rules and regulations as may be prescribed by the commissioner of agriculture, with the approval of the board of commissioners of State institutions. The supervisors of State convicts shall inspect and supervise all county convict camps. (Acts 1909, ch. 5963; Acts 1913, ch. 6537.)

Persons confined in the county jail under sentence of a court may be worked on the roads of the county. If the number of convicts in any county at any time be less than five, the county commissioners may arrange with the county commissioners of any other county for an exchange of prisoners. The cost of guarding and maintaining such prisoners shall be paid by the county in which they are worked. Ten hours shall constitute a day's labor for all such convicts. Every such convict shall be entitled to receive, together with subsistence, a credit at the rate of 30 cents per diem on account of fines and costs. (G. S. 1906, secs. 4110, 4111, 4113.)

The sheriff shall be allowed the following fees for feeding prisoners: For feeding 10 prisoners, or less, 50 cents per day each; and over 10 prisoners, 40 cents per day each. (Acts 1915, ch. 6898.)

GEORGIA.

State.—Every crime declared to be a misdemeanor is punishable in the discretion of the judge by a fine of not to exceed $1,000; imprisonment not to exceed six months; work in the chain gang on the public roads or on such other public works as the county or State authorities may employ the chain gang not to exceed 12 months. All male felony convicts, except such as are now required by law to be kept at the State farm, may be employed by the authorities of the several counties and municipalities upon the public roads, bridges, or other public works thereof. On or before the 10th day of February annually, the prison commission shall communicate with the county authorities of the State and ascertain those counties desiring to use convict labor upon their public roads, and said county authorities shall advise the prison commission, in writing, whether they desire so to use such labor and the number desired. The convicts shall be apportioned among the counties according to population. Convicts may be awarded to counties other than the one in which the conviction was had. One county may, upon the approval of the prison commission, deliver its quota of convicts to another county, to be used on the roads and bridges thereof, the counties so receiving such convicts to have the right to compensate the county from which the convicts came, with work upon its roads, or by the exchange of an equal number of convicts. The prison commission may, when in funds, purchase road machinery, appliances, and teams, and equip and organize road-working forces, the same to be used for the construction and repair of roads and bridges in counties not using their convicts under the preceding provisions, when requested by the authorities thereof so to do, the work to be done as nearly as practicable in proportion to the convicts which would have been assigned to such county in case it had worked its convicts, but as many convicts in addition to said proportion may be worked as any county is willing to pay the expense of, and as the commission may have at its disposal. The county in which convicts are worked shall pay the expenses thereof, including maintenance of equipment and all material required for the work done in the county. If all convicts are not disposed of under the preceding provisions, the prison commission is hereby authorized to place convicts in counties desiring to use them in excess of their quota. If after the counties have been provided with convicts there shall still remain any convicts not otherwise disposed of, then the privilege conferred upon counties herein shall be extended to municipalities, which may hire convicts from the prison commission at the price of $100 per capita per annum.

Any county may purchase or rent, and maintain a farm and cultivate same with convict labor in connection with working its convicts on its public roads and bridges, all products and supplies arising therefrom to be used for the support of the convicts, for the improvement of its public roads and bridges, and in support of county institutions. All convicts and all convict camps shall be under the direct supervision of the prison commission, which shall prescribe rules and regulations for governing the same, subject to the approval of the governor, and shall require the observance and maintenance of sanitary rules and appliances. The net proceeds from the disposition of convicts to municipalities or otherwise shall be used at its option by the prison commission in working convicts upon the public roads or works of counties not electing to utilize their allotment of convicts; and in case said commission shall elect not to work the roads in any one or more of said counties, then the pro rata of said funds for said counties shall be paid into their respective treasuries to be used for road purposes only. The prison commission may purchase or lease for five years one or more tracts of land conveniently located for working the convicts thereon; and the State farm shall be used as far as possible for making supplies of all kinds for maintaining the convicts, either in farm products or manufacturing articles for the use of the convicts and State sanitarium and other State institutions. If the prison commission has on hand convicts not provided for under the foregoing sections of this act, they may be placed upon said farms to work. Not to exceed four supervisors may be employed by said prison commission, to visit the various counties, to inspect the convicts and their work, and to perform such other duties as may be required of them. If practicable, civil engineers shall be selected for these positions. The commission shall also appoint such wardens and guards as may be necessary. (Ex. sess. 1908, act No. 4.)

Counties.—The authorities of any two or more counties having charge of the county public works may act jointly and cooperate in establishing, improving, and maintaining a system of intercounty public roads, and may jointly create a chain gang from the convicts of such counties sentenced for misdemeanors or felonies. Such chain gang shall be put to work on such system of roads under such rules and regulations as said authorities may prescribe. The cost of such work shall be paid by the counties in such proportions as the authorities thereof shall determine. (Political Code of 1911, Title VI, secs. 428–431.)

The commissioners of roads and revenues, or the ordinary, as the case may be, shall repair the public roads as follows: By chain gang organized from misdemeanor convicts of the county, or of any other county from which such convicts may be obtained without cost; by free labor and those who do not pay the commutation tax; or by contract; or by a combination of such methods. Such authorities may purchase and provide any machinery, tools, stockades, and other such equipment necessary in handling and working the chain gang. (Political Code of 1911, secs. 697–698.)

IDAHO.

State.—Subject to such rules and regulations as may be adopted by the State board of prison commissioners, the State highway commission may make requisition upon the warden of the State penitentiary for such number of the convicts confined therein as in his judgment are physically able to work upon any of the highways to be constructed by said State highway commission. Such convicts shall be worked under the general direction and supervision of the State highway commission, subject to such rules, regulations, and safeguards as may be prescribed by said board of prison commissioners. The State highway commission shall cause to be paid out of the State highway fund $5 per month to each convict so worked, and also the expense of transporting, guarding, and subsistence of each convict while away from the State penitentiary, less the estimated average cost to the State of his subsistence had he remained at the penitentiary. (Acts 1913, ch. 179, as amended, acts 1915, ch. 64.)

Counties.—The county commissioners of the several counties may employ inmates of the county jail on public roads or other county work under such regulations as they may prescribe. A person serving a sentence in the county jail who has a good record and performs the tasks assigned him in an orderly manner, shall, on recommendation of the sheriff and prosecuting attorney, be allowed five days off of each month of his sentence, by the probate judge. (Acts 1915, chs. 77 and 130.)

ILLINOIS.

State.—The board of prison industries shall, upon requisition of the State highway commission, employ prisoners in the penal and reformatory institutions of the State in the manufacture of tile and culvert pipe, road machinery, tools, and appliances, and in the preparation of road and ballasting materials. All such materials so manufactured shall be placed upon railroad cars to be forwarded to proper destination. Application for such materials may be made to the State highway commission by county or township road officials, as the case may be, in such quantities as may be needed for the construction or repair of their roads, obligating themselves to use such materials according to rules and regulations formulated and approved by the State highway commission. The State highway commission may negotiate with railroad lines for rates of transportation on all such material, machinery, and tools, and may contract with such railroads to pay for same in ballasting material. (Acts 1905, ch. 108, as amended in 1907.)

The commissioners of the Northern Illinois Penitentiary, commissioners of the Southern Illinois Penitentiary, and the board of managers of the Pontiac Reformatory may employ convicts sentenced for terms not exceeding five years, or who have not more than five years to serve to complete their sentence, in working on the public roads or in preparing road materials outside the walls of such institutions. Upon written request of the county or township road officials, as the case may be, said penitentiary commissioners and the board of managers of said reformatory shall detail such convicts as in their judgment shall seem proper, not exceeding the number requested, to be worked under such terms and conditions as the said penitentiary commissioners and board of managers may prescribe. Such local road officials shall pay all additional expenses for guarding such convicts while so worked in their respective townships, road districts, or counties. (Acts 1913, S. B., 539.)

INDIANA.

State.—The board of trustees of the Indiana Reformatory, and the board of control of the Indiana State Prison, may work the inmates thereof, or any number of such inmates, upon the public highways of the State, whenever there is no labor at which they may be employed within the walls of such institutions. Said boards may adopt rules and regulations for the care, control, and safety of such inmates while so employed, and may enter into an agreement with the board of commissioners of any county, or the township trustee of any township, to work such inmates upon the highways of such county or township, and such agreement shall provide the compensation such county or township shall pay said boards for the labor of such inmates. In order to carry out such agreements, said boards may purchase necessary tools, apparatus, appliances, and movable places of confinement for such inmates and employ a superintendent to have charge of such work. Said board of county commissioners, or township trustees, as the case may be, may purchase all materials necessary to perform such work. Said boards may enter into similar agreements with any commission or board that hereafter may be authorized by law to improve the public highways of the State. (Acts 1913, ch. 83.)

Counties.—All able-bodied male prisoners sentenced to any county jail or workhouse, either for punishment or for nonpayment of fines or costs, may be put at hard labor on the public roads or highways, or upon any other public work, under such rules and regulations as the board of county commissioners may prescribe. The cost of guarding such prisoners while so employed shall be paid from the county treasury. (Burn's Anno. Stats., 1908.)

IOWA.

State.—The board of control of State institutions, with the advice of the warden of any penal institution of the State, may permit any able-bodied male prisoners to work upon the highways or any other public works of the State, but no prisoner shall be so worked whose health might thereby be impaired, or whose character is such that he would probably be unruly or attempt to escape. No prisoner who is opposed to so working shall be required to do so. Prisoners so employed shall at all times be under the charge and jurisdiction of the warden of the institution to which sentenced, and said warden shall designate guards, officers, or agents, to direct and supervise such prisoners. The State highway commission shall supervise the work performed on the highways, but may cooperate with boards of supervisors and local officials in the performance of same. Said board of control and warden shall prescribe the conditions and manner of keeping and caring for such prisoners. County boards of supervisors, or other local road officials, desiring to use prisoners upon the highways in their respective jurisdictions, may apply therefor to the State highway commission, specifying the number desired, character of work, and the amount that will be paid for such labor. If said commission shall approve the application, it shall be submitted to the board of control and warden, who shall arrange the details of the contract with such board of supervisors or other local road officials. The compensation agreed upon for such labor may be paid from any fund available for road and bridge work, and said board of control may allow a part of such compensation, over and above the cost of maintenance, to such prisoners as shall perform such labor and send a portion thereof to those dependent upon them. Prisoners shall not work in clothing which will make them look ridiculous or unduly conspicuous. (35 G. A., ch. 134.)

Counties.—Able-bodied male persons over 16 and under 50 years of age, imprisoned in any jail, may be required to labor during the whole or a part of the term of imprisonment, at the discretion of the court imposing sentence. Such work may be on the streets, on the public roads, or at such other places in the county as the person having charge of the prisoners may direct, not exceeding eight hours per day. When imprisonment is for violation of State statute, the sheriff shall superintend the work and furnish tools and materials, if necessary, at expense of the county, and the county shall be entitled to the benefit of such labor. If such imprisonment is for violation of any ordinance, by-law, or other regulation of a city or town, the marshal shall superintend the labor and furnish tools and materials, if necessary, at expense of such city or town entitled to the benefit of the labor of such convicts. (Code 1873; secs. 4736–4739; 21 G. A., ch. 153.)

KANSAS.

State.—The warden of the State penitentiary shall employ the surplus convict labor in extending and repairing the State and county roads, and upon other work exclusively for the benefit of the State. (Acts 1907, ch. 20; Acts 1915, ch. 58.)

Upon written request of the board of commissioners of any county or of the mayor or councilmen or the commissioners of any city or town, the warden of the Kansas State Penitentiary may, in his discretion, detail convicts to work upon such roads, streets, or alleys as may be designated in said request; provided that such county, city, or town, respectively, shall pay all additional expenses of guarding said convicts while so employed and furnish necessary materials and tools, and shall also pay to said warden the sum of $1 per day for each convict so furnished, which sum, after deducting the cost of maintenance and retention, shall be paid to those dependent on such convict, if any, otherwise it shall be paid to such convict on his discharge. Said convicts shall not be used in building any bridge or like structure which requires skilled labor. Convicts may be granted as additional good time allowance one day out of each three so employed, conditioned upon good behavior. (Acts 1913, ch. 219.)

Counties.—The board of county commissioners of any county may properly shackle and work, under such rules and regulations as said board may prescribe, male prisoners committed to jail for nonpayment of fines and costs. Said board may establish a county stoneyard and work such prisoners at breaking stone for road and street purposes. Stone so crushed may be sold or disposed of on such terms as said board may deem advisable, or, if it can not be sold, it may be used in improving some designated road or street. The proceeds from the sale of such stone shall be used to pay for stone delivered at the stoneyard and the remainder applied to payment of the fine and costs against the person breaking the same. Such prisoner may, if he shall so desire, under certain requirements, agree to do a certain amount of work on some highway in full satisfaction of such fine and costs and may be released from jail for that purpose. Prisoners shall be allowed $1 for each day's labor performed in good faith, or a specified sum per cubic yard for breaking stone. (G. S. 1909, ch. 97, art. 18, secs. 6937–6943.)

KENTUCKY.

State.—The State may employ outside the walls of the penitentiary persons confined therein for felony in the construction, reconstructing, and maintaining public roads and bridges or in preparing road materials, or in aid of road and bridge work by the counties. (Amendment to the constitution adopted in 1914.)

Counties.—Persons sentenced to hard labor for nonpayment of fine and costs or as punishment for offense committed, shall be placed in the county workhouse, or at work upon some public work or road of the county, or upon the public works of any city or town in the county. The place and manner of working such prisoners shall be determined by the county judge, and he shall give preference to work on roads. When prisoners are worked on the county roads, the cost of feeding, lodging, and guarding shall be paid out of the road funds of the county; and when they are employed on the public works of any city or town, all such expenses shall be paid by such city or town. The county judge may appoint a manager and guards for each crew of prisoners, but no crew shall consist of less than three prisoners and not more than one man shall be paid to manage and guard less than 10 persons. The county court may prescribe rules and regulations for governing prisoners and those in charge of them. Any prisoner who may escape shall be fined from $20 to $100, or imprisoned for 10 to 15 days, either or both. All prisoners placed at hard labor shall be permitted to satisfy their fines and costs at the rate of $1 per day. (Acts 1914, ch. 89.)

LOUISIANA.

State.—Whenever in the opinion of the State highway engineer, convicts can be profitably worked upon the public roads, he shall apply to the board of control of the State penitentiary who shall furnish such convicts in case they are available. The labor performed by the convicts shall be furnished free of charge, provided that the cost of maintenance and operation shall be borne by the parish, municipality, or road district having the work performed and paid out of the fund available for said work. The board of control of the State penitentiary shall retain control and supervision over said convicts in the same manner and to the same extent as if they were upon State farms or in the penitentiary walls. (Act No. 49, Sec. 16.)

Parishes.—In all convictions of crime punishable by imprisonment at hard labor, but not necessarily so, the judge may sentence the person so convicted to work on the public works, roads, or streets of the parish or city in which the crime was committed; provided, that when a fine is imposed as part of the penalty in such cases, the judge may, for nonpayment of such fine and costs, enforce payment thereof by sentence of additional labor at the rate of $1 per day. Police juries may prescribe rules and regulations for the discipline and working of such convicts, but no convict shall be required to wear a ball and chain or other symbol of degredation, nor shall they be required to work more than 10 hours per day. (Acts 1878, No. 38.)

Able-bodied males, over 18 and under 50 years of age, sentenced to imprisonment in the parish jail for crime or for nonpayment of a fine, shall be worked upon the public roads or other public works, or shall be leased to some one person for the purpose of working them within the parish. Convicts shall not be so held and worked for fines and costs for more than two years, and for good conduct and efficient service they shall be entitled to a deduction of one-sixth from their term of imprisonment. The police jury may prescribe rules and regulations for the government and control of such prisoners. Any convict who shall escape, or attempt to escape, shall have his sentence increased by 10 per cent of the unexpired term and sufficient additional time to cover the costs incident thereto. The wages of convicts shall vary from $2 to $16 per month while so worked. The police jury may employ necessary gaurds. (Acts 1908, No. 204.)

MAINE.

Counties.—In counties not having established county workhouses, the county commissioners, at county expense, shall provide some suitable place, materials, and implements for breaking stone suitable for road-building purposes, and shall cause certain prisoners to be worked thereat. Said county commissioners may prescribe needful rules and regulations for the government and control of such prisoners and the prosecution of such work. (R. S. 1903, ch. 80.)

Upon written application of the county commissioners, or the municipal officers of any town, the board of prison and jail inspectors may require that any male prisoner under sentence in jail shall be worked on the public ways or in preparing road materials, under such regulations as said board of inspectors may prescribe. (Acts of 1905, ch. 126.)

MARYLAND.

State.—The State roads commission may establish a stone-crushing plant or plants, and may rent, purchase, or condemn stone quarries, or other materials, to produce road materials available most economically for water or other transportation, and do all things necessary and proper in connection with purchasing, producing, accumulating, and distributing such materials. For the purpose of building, constructing, and maintaining any State roads and bridges, or for working in any stone quarry operated by the State roads commission, said commission may make requisition on the director of the Maryland house of correction for as many inmates thereof as may be necessary for said purposes, and said directors shall furnish such inmates with such guards and keepers as can be spared from duty at said house of correction. Additional guards and keepers shall be furnished by said commission, if necessary. Said commission, in conjunction with aforesaid board of directors, shall provide for the maintenance and safe-keeping of said inmates while so employed. (Ann. Code of 1911, act 91, secs. 51–61.)

MASSACHUSETTS.

State.—The board of prison commissioners may cause the prisoners in any jail or house of correction to be employed within the precincts thereof in preparing road material, but no machine except such as is operated by hand or foot power shall be used in connection therewith. The Massachusetts Highway Commission shall give to said prison commissioners such information as will enable them to direct such employment properly. Materials so prepared may be sold to the county commissioners or to city and town officers who have care of public roads. All materials not so sold shall be purchased by the Massachusetts Highway Commission for use on State highways; but the prison commissioners may cause any of said prisoners to be employed on material furnished by said highway commission which shall then pay for the labor of preparation. (Rev. Laws 1902, ch. 225, secs. 59–61.)

Prisoners removed to the temporary industrial camp for prisoners shall be governed and employed under regulations made by the prison commissioners. The Massachusetts Highway Commission and the Board of Agriculture, at request of the prison commissioners, shall furnish such information as will enable them to prosecute to best advantage the work of reclaiming and improving waste land and preparing road materials by hand labor. (Acts 1904, ch. 243.)

The superintendent of the prison camp and hospital at Rutland, with approval of the board of prison commissioners, may employ prisoners confined in the camp section thereof in the preparation of road material by the use of such machinery as said board may consider necessary. Receipts from the sale of products and materials resulting from the labor of such prisoners shall be paid into the State treasury monthly, and so much thereof as may be necessary used to pay the cost of providing machinery, equipment, and other things, including supervision, required in such operations. (Acts 1915, ch. 260.)

Counties.—The county commissioners of any county may make arrangements with the Massachusetts Highway Commission, or with officials of a city or town, to work prisoners from a jail or house of correction on any highway, or unimproved land, or with a private owner to improve waste or unused land. Prisoners so worked shall be in custody of the sheriff. For the labor of any prisoners so employed the county shall be paid such sums as may be agreed upon. (Acts 1913, ch. 633, as amended; Acts 1914, ch. 180, and 1915, ch. 177.)

MICHIGAN.

State.—Upon written request of the proper county, township, or district road officials, the boards of control of the State penal and reformatory institutions may detail such able-bodied convicts as to them shall seem proper, not exceeding the number requested, to work upon such highways as shall be designated in said requests. Such requests shall be accompanied by a bid price per day for such labor, and allotments shall be to the highest bidder, but the price paid for such work shall be not less than 50 cents per day. Such county, township, or district shall pay the cost of transportation from and to the institution from which such convicts are obtained, and shall provide or pay for the lodging and food and furnish necessary tools and materials. The expense of guarding, if guarding be necessary, shall be paid by the State. Such convicts may be used in preparing road materials at quarries, but they shall not be worked in building any bridge which requires skilled labor. Good-time allowance may be granted such convicts for good conduct. (P. A. 1911, No. 181.)

Counties.—The board of supervisors of any county may order that any or all able-bodied persons over 18 years of age under sentence of imprisonment in the county jail shall be required to work upon the public highways, or in preparing road materials, or at any other work for the benefit of the county. The commissioners of highways of any township, and the authorities of any city, village, or county institution, may apply for the labor of such convicts. Such prisoners shall be under the control and custody of the sheriff while so worked, and the work performed shall be under the direction of the proper authorities of such township, city, village, or institution who shall furnish necessary tools and materials. The sheriff shall feed such prisoners the same as if they were confined in the county jail. (Acts 1915, No. 132.)

MINNESOTA.

State.—The State board of control shall purchase necessary machinery and appliances, in addition to that now belonging to the State at the Minnesota State Reformatory, and cause the spalls and waste rock on the grounds of said reformatory to be suitably crushed for road-building purposes. Such crushed stone, in excess of the needs of the reformatory, shall be delivered f. o. b. at the quarries to the State highway commission, as it shall apply therefor, to be used in the construction and repair of public roads. (Acts 1909, ch. 229.)

Counties.—Able-bodied male prisoners, over 16 and under 50 years of age, confined in any county jail or village lockup, may be required to labor in the jail or jail yard, upon public roads or streets, or elsewhere in the county, not more than 10 hours per day. The court passing judgment shall specify whether imprisonment shall be at hard labor. Persons awaiting trial may be allowed, upon request, to so labor. When a sentence is for violation of a State law, the county shall pay a reasonable compensation to each prisoner, and such labor shall be performed under the direction of the county board, and superintended by the sheriff, who shall furnish necessary materials and tools; and in case imprisonment is for violation of any ordinance, by-law, or police regulation of a city or village, such compensation shall be paid by and the work done under the direction of the governing authorities thereof, who shall furnish necessary tools and materials. The earnings of prisoners may be paid to those dependent upon them. In case of imprisonment for nonpayment of fine and costs, $1.50 shall be credited thereon for each day's labor. For refusing to labor or obey orders relating thereto prisoners may be kept in solitary confinement on bread and water, but not for more than 10 days at a time nor for more than 90 days in all. The sheriff shall receive from the county fees for the board and washing of prisoners as follows: For an average number of 5 prisoners 57 cents per day each; for more than 5 and not more than 10, 50 cents per day each; and for 15 or more, 43 cents. (Rev. Laws 1905, secs. 5468–5472.)

MISSISSIPPI.

State.—The superintendent of the State penitentiary may work and keep in passable condition the public roads leading into the convict farms for a distance of 5 miles out, but not to exceed two such roads from any one farm, and said superintendent shall be amenable to the board of supervisors for the faithful performance of said work, in like manner as regular road overseers. (Acts 1910, ch. 167.)

Counties.—If a person be sentenced to imprisonment in the county jail, he may be disposed of by the board of supervisors as follows: He may be worked on a county farm, kept in jail, or worked on the public roads or on other work of a public character; but never under a contractor. Any prisoner so working who shall render efficient service and comply with all rules and regulations may have deducted from his fine and the term of imprisonment one-fourth thereof. The board of supervisors may prescribe and enforce regulations for working, guarding, keeping, clothing, and feeding such convicts, while so worked. Convicts are classified as follows: First class, male and female, over 18 and under 55 years old; second class, all others, male and female. The wages of convicts working on roads, public works, or farms, shall be fixed by the board of supervisors, within the following limits: First class, $8 to $20 per month; second class, $5 to $15 per month. Municipal authorities shall have similar power with reference to municipal prisoners. The board of supervisors may agree with the like board in any contiguous county, or counties, to own a farm in common upon which to work prisoners, or to work with prison labor the highways of the counties so agreeing, and similar arrangement may be made by said board with any municipality. In no case shall male and female or white and colored convicts be allowed to sleep in the same apartment, and as far as practicable they must be worked separately. Women must not be required to work on public roads, works, bridges, or streets. (Acts 1908, ch. 109, and House bill 352.)

Municipalities.—Municipalities are authorized to aid in working and keeping in repair public roads leading thereto, as far therefrom as the authorities thereof may deem proper, and may work their convicts for that purpose by contract entered into with the contractor of such roads, or with the board of supervisors. (Acts 1910, ch. 168.)

MISSOURI.

State.—The warden and inspectors of the penitentiary may, in their discretion, enter into contracts for the employment of not to exceed three hundred convicts of the State penitentiary upon the public roads and highways of the State, at such times and places and under such terms as they may deem proper. (Acts 1911, Senate bill 23, sec. 2.)

Counties.—The county court may order the sheriff or marshal to cause jail prisoners to work on the public roads or at breaking rock for road-building purposes; and when there are ten or more able-bodied male prisoners confined in the jail of any county, it shall be mandatory on said court to order them so worked. Said court may employ necessary guards. The road overseers or road commissioners of any road district or township wherein work is done shall direct such work, if so ordered by the county court. A lot of ground on which to work such prisoners at crushing rock may be purchased or rented, and the rock so crushed may be sold by the sheriff to any incorporated town or city, or, by order of the county court, it may be turned over to any road overseer for use on the public roads. A person imprisoned for nonpayment of a fine shall be credited $1 on such fine for each day he shall so work. (Rev. Stat. 1909, secs. 3732-3733, 4915-4916.)

MONTANA.

Counties.—Persons convicted of crime and sentenced to the county jail may be required by the board of county commissioners to work on the public roads under such rules and regulations as said board may prescribe. The sheriff may employ guards and shall provide necessary clothing, food, and bedding for all prisoners committed to jail and shall be allowed such fees therefor as said board may determine. Boards of county commissioners may do work on State roads with convict labor. (R. C. 1907, secs. 9772-9776; Acts 1913, ch. 78.)

NEBRASKA.

State.—The board of commissioners of State institutions shall provide labor for the prisoners; and no prisoner shall be hired out to contract, except as herein provided. Any county, city, or village, through its proper officers, may contract with the warden, subject to approval of said board, for prison labor to be used in building or repairing roads or streets, or on other public works, at a wage to be agreed upon; and such county, city, or village shall make satisfactory provision for boarding, lodging, safekeeping, and guarding all such prisoners. As a matter of discipline, the warden may make deductions from the earnings of convicts for violation of a rule or for any misconduct. One-half the amount credited to each convict shall constitute a fund for the relief of those dependent upon him, and shall be paid to such dependent persons on order of the board of commissioners of State institutions. Said board may grant to prisoners employed outside the prison inclosure and to those making satisfactory progress in the prison school a deduction of time from their sentences, in addition to that otherwise granted by law, conditioned on good behavior and obedience to rules, but such deductions shall not exceed one month from each year of the sentence. (R. S. 1913, secs. 7317-7318, 7320-7322, 7324, as amended; Acts 1915, ch. 137, and ch. 240, 1915.)

Counties.—The county board of each county having a population of over 2,000 and under 100,000 and the mayor and council or legislative body of any city having a population of over 5,000 and less than 100,000 shall provide for the employment of prisoners sentenced to the county jail or committed to jail for nonpayment of any fine. (Acts 1915, ch. 70.)

NEVADA.

State.—When any prisoner shall be discharged from the State prison, either by expiration of sentence or pardon, the warden shall furnish him $25 in cash, to be paid out of the State prison fund. (R. L. 1912, sec. 7596.)

The board of State-prison commissioners shall detail for work on the public highways of the State such male convicts in the State prison as it may deem suitable for such detail, excepting prisoners under death sentence; provided that such detail shall be voluntary on the part of the convict. Convicts so detailed shall be under the general direction of the warden and guards appointed by him and subject to such rules and regulations as said board shall establish. Prisoners shall not be required to wear stripes, and for infractions of the rules the maximum punishment shall be a return to confinement in the penitentiary and forfeiture of credits. For good behavior and faithful work, convicts so detailed shall be allowed 10 days' time off their sentences for each month of work in addition to the time off otherwise allowed by law; and in addition thereto each convict shall be allowed 10 cents for each day's labor, which may be paid those dependent upon him for support or allowed to accumulate and be paid to him on his discharge. Said board of prison commissioners, on recommendation of the State engineer or the county surveyor, shall determine upon what roads such convicts shall be worked and shall pass upon the plans and specifications of said engineer or county surveyor in respect thereto. The State engineer shall have general supervision and direction of the road work done. Counties shall, at their own expense, construct bridges or other structures requiring skilled labor, but no convict shall be employed thereon. Counties may be required to contribute in part to the expense of maintenance of convicts. All expenditures necessary in carrying out the foregoing, including tools, implements, horses, wagons, tents, bedding, clothing, tobacco, medicine, and commissary materials and supplies shall be paid from the general road fund, except that part payment for clothing and commissary supplies, not exceeding 50 cents per day per convict, shall be paid from any appropriation made for support and maintenance of the State prison. (R. L. 1912, secs. 7598–7602, and Acts 1913, ch. 288.)

Every convict not guilty of infraction of the rules and regulations, and who shall faithfully perform the duties assigned him, shall be allowed from his term of sentence a deduction of two months for each of the first two years; four months for each of the second two years; and five months for each remaining year. (R. L. 1912, sec. 7585.)

Counties.—The board of county commissioners of the several counties may, by proper order, establish a branch county jail in any town in the county and provide that persons charged with or convicted of a misdemeanor in such town or other town or townships mentioned in such order shall be imprisoned in such branch jail instead of the county jail at the county seat. Said board in any county where such branch jail is established may direct the jailor in charge of same to work the prisoners therein confined on the streets of such town or on the public roads of the district or township wherein such jail is located. (R. L. 1912, secs. 7514–7616.)

The board of county commissioners in each county, the mayor and board of aldermen of each incorporated city, and the board of trustees of each incorporated town, may make all necessary arrangements for working any prisoners committed to any jails in such county, city, or town upon the roads, streets, or public works thereof, for at least six hours per day. The sheriff of the county, the chief of police of a city, and the marshal of a town, respectively, shall have charge of such prisoners. Any prisoner who shall be disobedient or disorderly may be confined in a dark and solitary cell. Prisoners who shall be obedient and faithful shall have five days per month deducted from the term of sentence. (R. L. 1912, secs. 7617–7622.)

NEW JERSEY.

State.—The State commissioner of public roads may make application to the prison labor commission for any number of prisoners confined in the State penal institutions to labor on the public roads. Said prison labor commission, in conjunction with the governing body of the institution from which such prisoners are to be detailed, shall determine the number to be assigned, the cost of transportation and maintenance, the compensation for labor, and may enter into an agreement with said commissioner of public roads for payment of said cost of transportation and maintenance, or any portion thereof. The governing body of the institution from which such prisoners are to be detailed shall fix all rules of discipline and shall detail necessary guards for the control and safe-keeping of the inmates so detailed. All such work shall be performed under the supervision of the State commissioner of public roads, who may lawfully expend any moneys available for construction, repair, and maintenance of roads to meet the cost, or any portion of such cost, of housing, feeding, and guarding such prisoners while at work, or for purchase of tools, machinery, supplies, and road-building materials needed. (Acts 1912, ch. 223, as amended; Acts 1913, ch. 290.)

"State prison" shall be taken to include the present existing prison in the city of Trenton, and any and all State farms, camps, quarries, or grounds where convicts sentenced to the State prison may be kept, housed, or employed. Its management shall be vested in a board of inspectors consisting of six members appointed by the governor, with the advice and consent of the senate, for terms of six years. The said board of inspectors shall have exclusive management of the State prison, and shall have power to make rules and regulations for the government and control thereof. All expenditures shall be from appropriations made therefor, and earnings shall be turned into the State treasury. A keeper of the State prison shall be appointed by the governor, on advice and consent of the senate, for a five-year term, and he shall be the executive officer thereof and shall appoint all employees, including deputies, guards, and physicians. Nothing herein shall prevent the board of inspectors from entering into an agreement with the State commissioner of public roads, or other department of the State government, for the employment of prisoners on public work. (Acts 1914, ch. 271, as amended; Acts 1915, ch. 390.)

Appropriations are made annually to meet transportation expenses of prisoners and guards to and from farms and camps. (Acts 1915, chs. 403 and 405.)

Counties.—The board of chosen freeholders of any county may cause prisoners under sentence, or committed for nonpayment of fine and costs, or in default of bond for nonsupport of family, in the county jail or other county penal institution, except females and those incapable of manual labor, or so many of them as may be required, to work on the public roads of such county, and also upon the grounds of any county institution, and said board may pay the warden of such penal institutions such sum, not exceeding 50 cents per day for each day of eight hours' work performed by such prisoners, as shall be fixed by the board or the committee having charge of such institution. The amount so paid, less costs, if any, shall be held by the warden for the benefit of such prisoner on his discharge, or may be by said warden paid, on written order of the committing magistrate, to the dependent wife, minor child or children, or aged, infirm, or dependent parents, if any there be, of such prisoners; provided, that any moneys expended under the provisions hereof shall be paid from the appropriation in such county for the maintenance of its roads and highways. (Acts 1912, ch. 223, and 1915, ch. 119.)

NEW MEXICO.

State.—The act creating the State highway commission provides that convict labor shall be used in the work to be done thereunder, and that the board of penitentiary commissioners shall, upon demand of the State highway commission, furnish such number of convicts as shall be available for such work, together with necessary guards. The expense of employing and transporting such guards, and of transporting and maintaining such prisoners while so employed, shall be paid by the State highway commission out of funds provided for said commission. (Acts 1909, ch. 42.)

NEW YORK.

State.—The superintendent of State prisons may employ, or cause to be employed, convicts confined in the State prison on the repair of State and county highways upon request of the State commission of highways, and also in the improvement or repair of any other highways. The expense of maintenance of such convicts while employed in repairing a State or county highway shall be paid by the State commission of highways, in the same manner as other expenses in repairing such highways. The agent and warden of each prison may make such rules as he may deem necessary for the proper care, custody, and control of such prisoners while so employed, subject to approval of the superintendent of State prisons. The agent and warden of each prison may designate, subject to the approval of said superintendent, the highways and portions thereof on which such labor shall be employed; and such portions so designated and approved, except portions of a State or county highway, shall be under his control during such work, and the State highway commission shall fix the grade and width and direct the manner in which the work shall be done. The superintendent of State prisons may purchase any machinery, tools, and materials necessary in such employment, except on a State or county highway. (Prison Law, sec. 179, as amended; Laws 1914, ch. 60.)

The board of supervisors of a county, or the town board of a town, in which any portion of a State or county highway is situated, may present proposals and be awarded a contract for the construction or improvement of such highway as provided in this article, for and on behalf of such county or town. When such contract is entered into,the board thereby undertaking to construct or improve a highway or section thereof, may, by resolution, direct the person or persons designated for carrying out the contract to apply to the superintendent of State prisons for convict labor in the construction of such highway. The resolution shall specify the maximum number of convicts to be applied for. Such designated person or persons shall make such request in writing, accompanied by a copy of the resolution, and said superintendent may detail the number of convicts so requested, or so many thereof as may be available, who shall be under the immediate charge and custody of the officers and guards detailed by said superintendent, except that the work shall be directed by the engineers and foremen of the State highway department. The expense of maintenance of such convicts shall be paid by the county or town entering into contract from funds due thereon. A county or town may purchase machinery or tools for the construction of a highway or section thereof, under any such contract, out of moneys to be paid thereon, (Sec. 131, highway law.)

County.—After satisfying himself that proper quarters can be secured, the town superintendent may, with consent of town board, request the supervisor of the town, under the provisions of section 93 of the county law, to procure prisoners serving sentence in the county jail, for general work on the public highways of the town. (Sec. 70, highway law.)

NORTH CAROLINA.

State.—Any county, township, or road district desiring to use convict labor on highways shall apply first to the geologic and economic survey to lay out and make plans for said work, or to approve plans already made, and said county, township, or road district shall then apply to the board of State prison directors for the number of convicts desired, this number in no case to be less than forty. Said board of directors, as soon as possible after receipt of the application and the approval of the council of state, shall furnish the labor requested and proceed to improve the highway under the direction of the State geologic survey. No such county, township, or district may use at any time more than 100 convicts if an application from another county is pending and no convicts are available for it. Such counties, townships, or road districts shall pay to the State not less than $1 per day for each convict, shall furnish quarters to be approved by the board of prison directors, and shall furnish pure drinking water, firewood for camp use, and overseers to direct the work. All other expenses of every kind shall be borne by the board of prison directors. The State farm or penitentiary authorities or council of state shall at all times reserve a sufficient number of convicts to cultivate the State farm. (Acts 1913, ex. sess., ch. 37.)

Counties.—The board of commissioners of the several counties, or other proper county authorities, and the mayor and intendant of the several cities and towns of the State, may provide, under such rules and regulations as they may deem best, for the employment on the public streets, highways, or works, or other labor for corporations, of all persons confined in the jails in their respective counties, cities, and towns, upon conviction of any crime or misdemeanor, or for failure to enter into bond for keeping the peace, or for failure to pay all the costs which they are adjudged to pay. Said board of county commissioners may levy a special tax annually, as other taxes are levied, for the purpose of paying the expenses of said convicts, the building of stockades, etc., which expenses shall be paid by the counties taking advantage of this chapter. (Pell's Rev. of 1908, sec. 1318 and ch. 24.)

It is a misdemeanor to work females on streets or roads. (Pell's Rev. of 1908, ch. 81, sec. 3596.)

Every convict sentenced to work upon the public roads who shall perform faithfully the duties assigned him shall be entitled to a deduction of five days from each month of his sentence. Any convict escaping or attempting to escape shall forfeit any and all such deductions accrued up to the time of such escape or attempted escape. (Acts of 1913, ch. 167.)

NORTH DAKOTA.

State.—The board of control of the penal and charitable institutions, and the warden of the State penitentiary, shall employ all prisoners sentenced to the State penitentiary in all necessary work in maintaining the institution, or in carrying on the work of the industries established thereat, or at other State institutions, or on the public highways of the State, and shall prescribe rules and regulations relating to the care, treatment, and management of such prisoners. Such prisoners shall be employed under proper supervisors or officers, and may be employed upon the public highways of any county when an agreement has been entered into by the State board of control and the board of commissioners of such county, upon the same conditions as the employment of prisoners at State institutions. The county shall pay all salaries and necessary expense of maintenance, including cost of transportation to and from the penitentiary, and furnish necessary tools and equipment required in carrying on said work. Prisoners so worked shall receive not less than 10 nor more than 25 cents per day for work actually performed, the maximum compensation to be determined by the State board of control. Prisoners so employed shall be placed on their honor not to attempt to escape. They shall wear plain, inconspicuous garb and shall not be required to work more than 10 hours per day. The earnings of each inmate of the penitentiary to whom money is paid shall be distributed by the warden monthly in the "temporary aid account," "the prisoners' general benefit fund," and the personal account of each prisoner and the "dependent relative" account of such prisoners as have relatives dependent upon them for support, all of which accounts shall be kept by the warden. Said warden, with the approval of the State board of control, shall establish rules and regulations relating to the conduct of prisoners and shall prescribe penalties for violations thereof. Upon recommendation of the warden, the board of control may allow extra good time to prisoners in addition to the good time otherwise allowed by law. In computing such extra good time it shall in no case exceed the good time now provided by law, and it shall be conditioned on good conduct and diligent work. (Acts 1915, ch. 191.)

OHIO.

State.—The boards of managers of the penitentiary and of the reformatory, so far as practicable, shall cause all prisoners serving sentences therein, physically capable, to be employed at hard labor not to exceed nine hours each day in the manufacture and production of supplies for such institutions, or for the State or political divisions thereof; or in the production of crushed stone, brick, tile, and culvert pipe. Such products as are used in the construction or repair of public roads shall be furnished the political divisions of the State at cost. Convicts from the penitentiary shall not be worked with those from the reformatory. The board of county commissioners, or trustees of a township, may apply to said board of managers for road material, machinery, tools, or other appliances so manufactured and needed by them, obligating themselves to use the same according to rules and regulations approved by the State highway commissioner. (Page and Adams Anno. Ohio Gen. Code, 1912.)

State and counties.—Whenever the State highway commissioner shall desire to use any number of prisoners confined in the State penitentiary or reformatory to work upon the State highways, known as the inter-county or main market roads, or to employ such prisoners in preparing road-building materials, he shall make requisition upon the warden or superintendent of the institution in which such prisoners are confined, stating the number desired and the place where they are to be employed. The rules and regulations under which prisoners shall work shall be prescribed by the prison authorities, but the actual work done shall be under the control of the State highway commissioner or those acting under his authority. Said highway commissioner may use any money available for the construction, repair, and maintenance of roads, to pay the cost of transportation and discipline of such prisoners and to purchase tools, machinery, supplies, and road-building materials for use in connection with the work of such prisoners. The amount to be paid said prison authorities, if any, for the use of such prisoners, shall be agreed upon between them and the said State highway commissioner, but the amount so paid shall not exceed the cost of transportation, maintenance, and discipline plus the amount to be credited to such prisoner on account of his labor upon such highways. County commissioners may make requisition in like manner for prisoners to work on the county highways or to manufacture road materials, and receive such prisoners on the same conditions as the State highway commissioner. County commissioners may also make requisition upon the authorities in charge of any workhouse for any number of prisoners confined therein, or upon any jailer for any number of prisoners sentenced thereto, and same, as available, shall be furnished upon the same conditions as above prescribed for State prisoners. Prisoners sentenced for nonpayment of fines and all persons convicted of crime and sentenced to imprisonment in the State reformatory or penitentiary or the county jail or workhouse, or other penal institution, shall be subject to labor hereunder. Any city having a workhouse may use its prisoners on its streets or in preparing materials for use on such streets; and any magistrate in a city or village not having a workhouse may sentence prisoners convicted therein so to work. Persons confined in such penal institutions because unable to give bond may, at their request, work upon roads and streets, or in manufacturing materials, the same as persons convicted. The State highway commissioner, county commissioners, or proper city or village authorities may provide for the use of prison labor in connection with contracts let to private individuals for the construction, maintenance, and repair of roads and streets; but the discipline and legal custody of such prisoners shall remain in the respective institutions furnishing them. If any prisoner shall not perform his work satisfactorily, he shall be taken from the road force at the request of the proper authorities and another substituted. On or before September 1 each year, the State highway commissioner and the county commissioners shall report to the prison authorities an estimate of the amount and kind of road materials that will be needed the ensuing year, so that said prison authorities, if practicable, may arrange to manufacture same. The State highway commissioner shall include in his annual report a full statement of the amount, cost, etc., of the convict labor used; and he shall require such reports as he may deem necessary from county commissioners and other officials using prison labor. Prison authorities shall, before January 1 each year, advise the State highway commissioner and the county commissioners of the probable number of prisoners that will be available for work upon roads during the year. The guards, if any, shall, so far as possible, be selected from men who are competent to supervise the work under construction. Any prisoner attempting to escape shall lose any credits accrued to him on his prison term for good behavior, and the authorities having charge of the prison from which said prisoners are detailed may, by special regulation, provide for additional credit on the terms of such prisoners for good behavior. County commissioners may contract with the authorities in charge of any workhouse or penal institution of any other county or city for the use of convicts on the roads, or in the manufacture of road materials. The authorities of the various institutions having custody and control of such prisoners, and the various authorities of the State, counties, cities, and villages having charge of roads and streets, shall have full power and authority to do all things necessary to make the provisions hereof effective for the use of prison labor on the highways and streets, and the authorities having charge of said roads and streets shall have power to use any of the moneys provided therefor in any way necessary for that purpose. (Acts 1915, Senate bill No. 125, secs. 261-279.)

Counties.—Boards of county commissioners may purchase or lease beds of limestone or other road-building material after same is approved by the State highway commissioner as being suitable, or such boards may lease and operate a plant for manufacturing brick or other road materials and supplies. When such purchase or lease is made the said board shall make necessary arrangements to work the county convicts thereat, such convicts to include those persons whose punishment, in whole or in part, is imprisonment in jail or workhouse, and all persons, physically capable, who are confined for failure to pay a fine or costs in a criminal prosecution. All such prisoners shall be under control of the board of county commissioners, who may enact all needful rules and regulations for the successful working of such prisoners, employ a superintendent and necessary guards and attendants, and levy an annual tax, as other taxes are levied, for paying the expenses of such convicts and for carrying out the purposes hereof. (Page and Adams Anno. Ohio Gen. Code, 1912, secs. 2229–2239.)

OKLAHOMA.

State.—The State board of public affairs and the department of highways are required to make all necessary arrangements for working State convicts upon the public highways of the State under the following conditions: (*a*) The State shall furnish all tools and machinery and draft animals out of funds appropriated for that purpose; (*b*) the furnishing of tentage, housing, quarters, and equipment pertaining to the custody of the prisoners shall be paid from prison funds available for the maintenance of such prisoners. Food, clothing, guarding, sanitary appliances, and medical attention for convicts in road camps shall be provided by the State the same as if the convicts remained at the State prison. The county desiring convicts to work upon the State roads must bear the cost of transporting the men, animals, tools, and guards, and shall furnish food for animals, board for guards, fuel and supplies for power machinery and ordinary repairs to same, paying therefor out of the county road and bridge fund. Metal, cement, stone, or other road-building materials shall be furnished by the county unless it is planned to produce same with convict labor, which is hereby authorized. The State board of public affairs shall formulate rules and regulations for the government of State convicts while at work on roads, including good-time allowance for good behavior and efficient service. The corporation commission may make and enforce rates for transportation of persons and freight in connection with such convict labor. Said work shall be performed on such roads and of such kind and character as designated by the board of county commissioners of the county where located, and the county shall bear all cost of materials. Convicts so worked shall be divided into groups of not exceeding 100 men each and only one group may be worked in a county at a time and not for more than five months in any one county in any one year, nor shall any two groups be worked in any county until all counties making application therefor shall have received their proportion of work by said convicts. (Rev. Laws 1910, sec. 7601, and Acts 1915, ch. 173, art. 5.)

Counties.—The board of county commissioners may purchase such equipment as may be necessary for employing convicts or other labor upon the public roads and may pay for same from either the court or road and bridge fund. Said board may work any convicts confined in the county jail, either as punishment for crime or in lieu of payment of fine and costs, upon the public highways and may employ such guards and other assistants as may be required. When in the judgment of said board the expense of working convicts upon the highways is too great on account of the small number available, or for any other reason, it may provide necessary apparatus and work such convicts in crushing rock for use on the public highways of the county. Any person working upon the public roads in lieu of payment of fine and costs shall be allowed a credit of $1 per day thereon. The board of county commissioners may, by agreement with the city council, receive such prisoners of any city, but for the services of such city convicts shall only pay the cost of maintenance. Said board shall purchase supplies for feeding and maintaining county convicts while at work from the lowest and best bidder, and shall furnish wholesome food in sufficient quantity and variety, together with medical attention when required. (Rev. Laws 1910, secs. 7590–7596, and Acts 1913, ch. 112.)

OREGON.

State.—The superintendent of the Oregon State Penitentiary shall furnish and use such convicts as he may deem reasonably safe for that purpose to do the work necessary to repair and properly improve the roads leading to certain State institutions. A competent road builder may be employed to direct such work, and he may employ extra guards and purchase necessary machinery, tools, and materials. Each convict so worked shall receive a credit upon his sentence of two days for each day he shall faithfully work; but if at any time he shall fail to so work he shall forfeit all or as many of said credits as said superintendent shall deem proper. (Lord's Oregon Laws, secs. 6436–6437.)

The State shall not contract with any private person, firm, or corporation for the labor of convicts of the State penitentiary. Upon written request of the county court of any county or of the superintendent of any State institution the governor may detail from the State penitentiary such convicts as in his judgment may seem proper for use on the public highways of such county. (Laws 1913, ch. 2.)

Fifty thousand dollars is appropriated to be used by the board of control of the State of Oregon to install and equip with necessary machinery such plants as in its discretion may seem wise. Said board may use such portion of the amount so appropriated as it may deem advisable in employing convicts from the Oregon State Penitentiary in road building in the State, and shall make all rules and regulations necessary for same. (Acts 1915, ch. 251.)

Counties.—Able-bodied convicts serving sentence in any city, town, or county jail or prison, as punishment for crime or in default of fine, may be placed by the county court under the control of any road supervisor, or other person appointed to take charge of such convicts, to be worked on the public roads of the county, or such other public work as said court may direct. The county court shall make rules and regulations in regard to the employment of such convicts and for allowance of compensation and credits in time for good behavior; provided that no credit in excess of 10 days per calendar month shall be allowed, and if imprisonment is for nonpayment of fine, such convict shall be made to labor at rate of $2 per day until such fine is paid. Any county court may transfer to the county court of any other county any of the convicts committed to its control, upon such terms and conditions as may be agreed upon by the county courts concerned. Any convict who shall refuse to work shall be fed bread and water until he shall signify his willingness to work. If any county shall have created a board of county commissioners, or other board or tribunal, to have charge of the management of the public roads of such county, it shall have the same power as the county court under this act. (Laws 1913, ch. 3.)

PENNSYLVANIA.

State.—All persons sentenced to the Eastern or Western Penitentiary, or to the Pennsylvania Industrial Reformatory at Huntington, or to any other correctional institution hereafter established by the State, physically capable of such labor, may be employed eight hours per day at hard labor for the purpose of manufacturing and producing supplies or materials for said institutions, or for the State or any county thereof, or for the purpose of industrial training or instruction, or in the manufacture and production of crushed stone, brick, tile, culvert pipe, or other material suitable for use in road building. A prison labor commission is created, to be composed of a member of the board of prison inspectors of each of said institutions, respectively, which said commission shall determine the amount, kind and character of machinery to be erected in such institutions, the industries to be carried on therein, the number and character of inmates, and shall arrange for the sale of the materials produced to the State, or any county, or to any public State institution. For the purchase of material, equipment, and machinery, a special appropriation of $75,000 was made to the said prison labor commission, to be known as the manufacturing fund, and receipts from the sales of manufactured articles shall be credited to said fund. Each prisoner shall be credited with wages for the time he actually works, the rate of such wages to be regulated at the discretion of the prison labor commission, but it shall not be less than 10 nor more than 50 cents per day. Three-fourths of the amount so credited or the entire amount if the prisoner so desires, shall constitute a fund for the relief of any persons dependent on such prisoner. In case there are no dependents the sum shall be deposited to the credit of the prisoner. (Acts 1915, No. 289.)

Counties.—The warden of any jail may detail for work on the public highways such convicts as he may deem advisable, except prisoners under sentence of death. Written request for such convicts shall be made by the State highway commissioner for all State roads; by the county commissioners for all county roads; by the township commissioners or township supervisors, as the case may be, for township roads, and by the mayor or burgess for all municipal streets. Such detail, however, shall be voluntary on the part of the prisoners. Convicts while so working shall be under general direction of the warden, or overseers appointed by him, and subject to such rules and regulations as he shall prescribe. Such convicts shall not be required to wear stripes. For infractions of the rules and regulations the maximum punishment shall be the summary return of the prisoner to confinement in the jail and the loss of all deductions from sentence to which he may be entitled at the time. Each convict shall be allowed 25 cents for each day he labors, which sum shall accummulate as a fund to be paid him on his discharge, in addition to the sum of money ordinarily given discharged convicts. On petition of any convict, the warden may pay such sum, or part thereof, in support of those dependent on such prisoner. Convicts shall for good conduct and faithful work be granted such good time in addition to that allowed by law as the governor may order, not to exceed 10 days in any calendar month. Convicts so employed shall not be used in building any bridge or other structure of like character, or do any work in connection therewith which requires the employment of skilled labor. (Acts 1915, No. 359.)

Every male prisoner in any jail or workhouse may be worked eight hours daily, but no steam, electricity, or other motive power shall be used in conducting such work. Such labor shall be classified, fixed, and established by a prison board, created for each county, and shall be performed in accordance with rules and reguulations prescribed by said board, and may be performed on the public highways. Preference shall be given to roads leading to county seats. Said prison boards are authorized to spend such sum of money, out of any money in the county treasury not otherwise appropriated, as may be required for the purchase of materials and tools adapted to the work, as per classification. The respective prison boards may employ such deputies and other officers as shall be necessary for the supervision, safe-keeping, and good conduct of such prisoners. Any prisoner who shall escape while so working shall be deemed to have committed a breach of prison, and shall be subject to the penalty provided therefor. (Acts June 18, 1897; Apr. 29, 1899; and Apr. 24, 1901.)

SOUTH CAROLINA.

General.—Any person serving a sentence of six months or more, life sentences excepted, either in the State penitentiary or any county jail, or upon the public works of any county, shall be entitled to have one-tenth of such sentence deducted for good behavior. (Acts 1914, No. 352.)

State.—The county supervisor from each county in the State may be allowed to use without charge, for the purpose of working the roads of the county, any of the convicts he may select of those sentenced from his county to the State penitentiary. Said convicts shall be under the absolute custody and control of the supervisor and whatever guards he may appoint. (Acts 1914, No. 366.)

The punishment for arson shall be death by hanging, but the jury may find a special verdict with recommendations to mercy, whereupon punishment may be reduced to a term of imprisonment in the county jail or at hard labor in the penitentiary or on the public highways, in the discretion of the court. (Acts 1915, No. 133.)

Where punishment of imprisonment is provided for crime, all able-bodied male convicts shall be sentenced, without regard to the length of sentence, to hard labor on the public works of the county in which convicted, if such county maintains a chain gang, and in the alternative to imprisonment in the county jail or the State penitentiary at hard labor. Races and sexes shall be kept separate. Should the supervisor or commissioner of any county find it impracticable or inconvenient to work any such convict, he may turn him over to the penitentiary authorities. (Acts 1914, No. 291.)

Counties.—All courts and municipal authorities having power to sentence convicts to imprisonment at hard labor shall sentence all able-bodied males to work upon the public works of the county or of the municipality. All such convicts shall be under the exclusive control of the county supervisor and by him formed into a county chain gang and required to work on the highways, bridges, ferries, and other public works of the county. Municipal convicts shall be so worked under proper municipal authorities. The county board of commissioners shall feed and provide suitable guards and appliances for safe-keeping said convicts, and shall provide all necessary tools and implements, all costs and expenses of which shall be paid out of the county road fund. Municipal authorities shall make like provision for municipal convicts. If in the judgment of the board of county commissioners the number of convicts available is insufficient to warrant the expense of maintaining a chain gang, the supervisor of such county may contract with the supervisor of any other county for hiring or exchanging such convicts. (Code of 1912, Vol. I, Title VI, secs. 956–962.)

The county commissioners shall not let to contract the repairing or building of any bridge which can be repaired or built by a chain-gang force. (Code of 1912, Vol. I, Title VI, secs. 1079–1081.)

SOUTH DAKOTA.

Counties.—Able-bodied male prisoners, over 18 and not more than 50 years of age, confined in any county jail, or any prison or lockup of any city or town, may be required to labor not more than eight hours per day upon the public roads or streets, or other public works. Persons awaiting trial may, at their request, be allowed to perform such labor. Each prisoner so laboring may be paid a reasonable compensation by the county if imprisoned for violation of State law and by the city or town if for violation of an ordinance, by-law, or regulation. Such compensation, or such portion thereof as the court shall direct, may be paid to the wife or dependents of such convict. When imprisonment is for violation of a State law and the prisoner is confined in the county jail, such labor shall be performed under the direction of the county board and superintended by the sheriff, who shall furnish necessary tools and materials at expense of the county. The officer in charge of such prisoners may use all reasonable means to prevent escape and to enforce obedience. For refusal to labor or obey orders in reference thereto a prisoner may be kept in solitary confinement on bread and water, but not for more than 10 days for any one offense, nor more than 90 days in all. For each day's labor the prisoner shall be credited $2 on any judgment for fine. (Acts 1915, ch. 257.)

TENNESSEE.

State.—The Tennessee Board of Control shall make rules, regulations, and contracts for the employment of inmates of the Tennessee State penitentiary and the Brushy Mountain Penitentiary on the highways of the State and on railroads to be built, and in operating the State farms, and on any and all roads necessary and of value to the State's properties. On or before March 1, each year, said board shall ascertain the number of prisoners available to work on roads and shall notify the county judge or the chairman of the county court of each county who may apply for such convicts. Said board shall fix and select the camps and prepare equipment for the working of such convicts, and such convicts and all machinery used by them shall be under the absolute control of such officers as may be designated by said board, but the work shall be done on such roads as may be designated by the county authorities. Not less than 50 prisoners shall be furnished to a county and they may be worked from April 1 to December 1. The rate of compensation for such inmates shall be fixed by said board and the county authorities by agreement, but shall not be less than $1 per ten-hour day. Said board may pay all necessary costs of transportation of prisoners, guards, and equipment out of the prison fund; and shall provide comfortable and sanitary quarters. The rules and regulations of the penitentiaries and all laws applicable shall apply to the discipline of such camps. The board may, in its discretion, contract with a county for building highways with convict labor, such contract to be made only upon authority of the governor and approval of the State engineer. Said board may employ and designate such person or persons deemed necessary as camp and road superintendents and as guards. (Acts 1915, ch. 114.)

Counties.—All persons confined in county jails or workhouses, either under sentence for crime or for nonpayment of fine and costs, shall be available for work on the public highways. (Code of 1896, Part I, secs. 1642–1644.)

The judge or chairman of the county court, the clerk of the county court, and the sheriff of each county are constituted a board for their respective counties to enter into contracts with public road commissioners, or with other officers or road contractors having superintendence of public road work, for the employment on such roads of prisoners confined in the county jails for nonpayment of fine and costs. The sheriff shall appoint guards for such prisoners, and the county court shall furnish said guards with picks to go on each prisoner to prevent his escape. Said prisoners may be worked eight hours per day on any of the public roads of the county, and shall receive 75 cents for each day's work in addition to the 25 cents otherwise allowed by law, which shall be credited on such fine and costs. Prisoners of two or more counties may be combined by said boards and worked on roads of said counties. (Acts 1899, ch. 358.)

All county prisoners subject to labor shall be employed, as far as practicable, on the public highways, and may be let to contractors who will employ them on the public roads, eight hours per day. County authorities shall name guards. (Acts 1899, ch. 368, sec. 7.)

TEXAS.

Counties.—County convicts shall be put to work upon the public roads, bridges, or other public works of the county when their labor can not be utilized in the county workhouse, or on the farm. They shall labor not less than eight nor more than 10 hours per day. Convicts so worked shall be properly guarded. A prisoner may avoid manual labor in the workhouse or elsewhere by payment into the county treasury of $1 per day for each day he would have to work. (Rev. Civil Stats., 1911, title 104, Art. 6238, 6246–6248.)

The commissioners' court shall require all male county convicts, not otherwise employed, to labor on the public roads, under such regulations as it may prescribe, and each convict so worked shall receive 50 cents, first on his fine and then on costs for each day he may labor. Said court shall at each term allow the court officers and witnesses such amount of their costs, not to exceed one-half, as have been so satisfied in full by labor, which shall be paid from the road and bridge fund. For faithful service and good behavior said court may grant a reasonable commutation of time for which a convict is committed, but not in any case more than one-tenth of the whole time. The commissioners' court may provide for necessary houses, prisons, clothing, bedding, food, medical attention, superintendents, and guards; and may prescribe such reasonable regulations and punishments as may be necessary to secure good work. (Rev. Civil Stats., 1911, title 119, secs. 6967, 6979.)

UTAH.

State.—The prisoners in the county jail may be required to work upon county roads under regulations made by the county board of commissioners, and prisoners in the State prison may be required to work upon State roads, or in providing road materials. State convicts so worked shall be under the authority and control of the State Road Commission, the State Board of Corrections, and the warden of the Utah State Prison, but actual supervision of the work shall be under such competent persons as may be selected by the State Road Commission. Such convicts shall not be worked more than eight hours per day, and the State Road Commission may designate from time to time the roads on which such labor shall be performed. Said State Road Commission shall cause surveys to be made and plans and specifications to be prepared, and shall designate the materials to be used. Rights of way for State roads to be improved by such convict labor shall be secured by the county commissioners. Bridges and culverts necessary on such roads shall, as far as practicable, be built with convict labor, and according to plans approved by the State Road Commission. Any materials necessary to be purchased for such bridges and culverts shall be paid for by the State Road Commission out of that portion of the State Road Fund available to the county where such bridge or culvert is located. Funds are provided by the legislature to pay extra guards and foremen and for the purchase of tools, implements, blasting materials, supplies, and equipment necessary in prosecuting said work. (Laws 1911, ch. 76.)

Counties.—The board of county commissioners may provide for working misdemeanor prisoners confined in the county jail, upon the public grounds, roads, streets, alleys, or public buildings, when such prisoners are liable to labor. (Acts 1911, ch. 119.)

VERMONT.

Counties.—All male prisoners under sentence in a county jail may be required by the sheriff to work not more than 10 hours each day within or without the walls of the jail. The labor to be performed shall be classified and fixed, from time to time, by the sheriff and shall be subject to such rules and regulations as he may prescribe, and said sheriff may require said prisoners to work on the public highways. Said sheriff may spend such sum as may be necessary for the purchase of materials and tools. The proceeds of such labor, if any, shall be applied in payment for such materials and tools, and one-half of any balance thereafter shall be turned over to the State treasurer and the remaining half shall be paid to the wife and minor children of said prisoner, if any there be, and if there are no such, then to him on his discharge. If a prisoner shall escape while employed without the jail walls he shall be guilty of prison breach and punishable accordingly. (Pub. Stats. 1906, secs. 6104–6107, as amended; acts 1915, Nos. 1 and 223.)

Sheriffs of the several counties may employ, or cause to be employed, able-bodied prisoners, confined in the county jails upon conviction for crime, in improving the public highways within a radius of 30 miles from such jail and outside of a city or incorporated village. Such sheriff, or keeper of each jail, may make such rules and regulations as he deems necessary for the care and safe-keeping of such prisoners, subject to approval of the attorney general and the governor. The State highway commissioner, subject to approval of the sheriff of each county, shall designate the highways upon which labor shall be performed; and such highways, or portions thereof, so designated shall be under the control of such State highway commissioner or his assistants during such work, but the care of the prisoners while so employed shall be under the sheriff or his deputies. Persons interfering with such prisoners while so employed are subject to arrest without warrant and to fine or imprisonment. (Acts 1912, No. 244.)

VIRGINIA.

State.—Persons convicted of crime and sentenced to the State penitentiary and persons convicted and confined in public jails, shall be delivered to the superintendent of the penitentiary and shall constitute the State convict road force. No prisoner under 16 years old shall be so worked, and it shall be discretionary with the court as to whether those over 16 and under 21 years old shall be worked. Persons convicted of violating city or town ordinances shall be primarily liable to work on the chain gang or public work within such city or town. The superintendent of the penitentiary shall be allowed for keeping and supporting such prisoners the fees allowed jailers for similar service, which are as follows: For each prisoner, per day, 40 cents; but where there are 3 and less than 10 prisoners, for each, 30 cents; and where there are more than 10 prisoners, for each, 25 cents; which fees shall be paid by the State for prisoners convicted of violations of State laws and by cities or towns for prisoners convicted of violation of the ordinances thereof. Rules and regulations in force at the penitentiary shall be applicable to the State convict road force, unless manifestly inconsistent, and unless the State highway commissioner shall deem it necessary to alter or amend them. If any jail prisoner shall escape and be recaptured, he may be sentenced to from 30 days to 6 months for such escape, and for sufficient additional time at 50 cents per day as will pay the cost of his recapture, such additional time not to exceed one year. The superintendent may discharge a prisoner wherever he may be in the State when his term shall expire, and shall furnish him transportation to the county or city from which he came and, if he need it, a suit of coarse clothing. Each prisoner so discharged may, in the discretion of the board of directors of the penitentiary, be allowed not exceeding $10. Said superintendent shall detail, or appoint with the approval of the State highway commissioner, guards for the convict road force. Persons competent to supervise the work under construction shall, as far as practicable, be detailed or appointed as guards. The said superintendent, with the approval of the State highway commissioner, may appoint an assistant to have charge of the said road force. A county which maintains and works a chain gang on its roads may retain its jail convicts in said chain gang. As far as practicable, and at the request of the State highway commissioner, trusties may be made of the convict road force. The superintendent shall provide suitable and movable quarters, wagons for transporting the convicts and camp fixtures, cooking utensils, beds, clothing, and food, in the same manner as for convicts in the penitentiary. The number of convicts desired for work in any county shall be sent to such county by the said superintendent on the requisition of the State highway commissioner. An engineer appointed by the State highway commissioner, and paid by the county having the benefit of his services, shall have charge and supervision of the work done by such convicts, and such work shall be done according to plans and specifications furnished by the said highway commissioner. Necessary medical attention shall be provided by the county in which a convict may be working. The cost of organizing, equipping, and working said convicts is provided for by the creation of the State convict road force fund, which consists of the fees allowed by law to jailers for supporting prisoners, and the sum of $145,000 appropriated therefor annually by the legislature. County authorities may arrange to improve any main traveled road by contract, and may secure the services of such number of convicts for work thereon as will amount to a contribution on the part of the State of not exceeding 40 per cent of the total contract price of such improvement, estimating such labor at $1 per day per convict. (Code of 1887, secs. 3532, 4147; Acts 1906, chs. 73, 74; Acts 1908, chs. 65, 84; Acts 1910, ch. 267; Acts 1912, ch. 58; and Acts 1914, ch. 199.)

Persons in jail and unable to arrange bail may, at their election and with approval of the Commonwealth's attorney, be worked in a chain gang or on the State convict road force. If such person be convicted when tried, he shall be credited with the time he shall so work on his sentence; or, if he be fined, he shall be credited with 50 cents on such fine for each day he shall have so worked; and if he be acquitted he shall be paid 50 cents for each day he shall have so labored. (Acts 1906, ch. 59.)

Counties.—In any county or city in which no chain gang has been organized the judge of the circuit court or of the corporation court of such city shall, upon application of the board of supervisors of any county in which a chain gang has been established order any person confined in the jail of his county or city and liable to work on chain gangs, to be delivered to such other county to be worked on its chain gang. The county receiving such prisoners shall keep and maintain them out of its road fund. (Code of 1904, title 16, ch. 43.)

The council of each city and town, and the board of supervisors of each county, or, if they do not act, the judge of the corporation court of such city or town, or of the circuit court of such county, may establish a chain gang in such city, town, or county to work the roads and streets therein. Only male prisoners above the age of 16 shall be worked in such chain gangs. If any county has not a chain gang of its own, such prisoners may be hired to any county, city, or town which has one. Such city or town council or county board of supervisors or the circuit or the corporation court judge shall prescribe necessary rules and regulations for governing and working such convicts and shall provide clothing and maintenance expenses. Such rules and regulations may be enforced by corporal punishment. Prisoners escaping may have one month added to their sentence. Persons held to labor for nonpayment of fine or costs shall be credited on same 50 cents for each day they shall so labor, but no persons shall be required to so work for more than six months for failure to pay such fine or costs. Persons so working shall receive the same credit on their sentence for good behavior as convicts in the penitentiary. (Code of 1904, title 16, ch. 43, secs. 3932-3937; acts 1908, ch. 354.)

Washington.

State.—The State highway board may, in its discretion, cause any State road to be constructed, either under contract or by force account; and if by force account the work shall be done by convict labor to the extent that same may be available and advantageously used. When any money shall be appropriated for any State road or roads, and the State highway board shall have determined to construct such road or roads by convict labor and free labor, as aforesaid, said board may purchase necessary road machinery and pay for same from the appropriation made for different roads in proportion to the use that will be made of it on each road. Persons physically able so to work who are confined in the State penitentiary and not engaged in other work by the State board of control may be worked on roads, and said board of control shall monthly certify to the State highway commissioner the number of prisoners available. Work done shall be under supervision of the State highway commissioner, but the control and management of all such prisoners shall be under supervision of the State board of control. The expense of the care, maintenance, and transportation of all such prisoners shall be paid out of the funds authorized to be used for the particular road on which such work is done, provided that a part of such expense equaling 25 cents per day per person employed shall be paid out of the appropriation for the maintenance of the particular institution from which such persons are taken. (Rem.-Bal., secs. 5869-1-2, 8575-1-3; Laws 1913, chs. 114, 132.)

State quarries.—The board of geological survey shall cause to be made an investigation of the road materials of the State and their location; and after such investigation the State highway commissioner shall select four or more sites for locating rock quarries and crushing plants for supplying materials suitable for road building, which said sites shall be acquired for the State by the State board of control. Whenever such site and quarry is procured, the State highway commissioner may forthwith erect thereon such stockades and buildings and purchase and install such rock-crushing plants, machinery, appliances, and tools as may be necessary for the keeping and working of State convicts thereat, under charge of the superintendent of the penitentiary. All rock so crushed shall, upon request of State highway commissioner, be loaded upon cars or vessels and there delivered to said commissioner for use in the construction or maintenance of State or State-aid roads. The surplus not so required may be disposed of by the State highway commissioner to counties, cities, or towns in the order of application therefor; and if the demand from such counties, cities, and towns shall exceed the supply it shall be equitably apportioned among them. All materials used by the State highway commissioner shall be paid for out of the appropriation for the particular road on which used, and all such material furnished to him or to such counties, cities, or towns shall be at a price of not less than 10 per cent above the estimated cost f. o. b. at place of production. Any additional surplus may be otherwise sold for not less than the cost of production. A "quarries rotary fund" is created, to consist of all moneys received from the sale of products of the quarries and some other sources of revenue. Such fund shall be used for operating such quarries. A superintendent of quarries may be appointed by the State highway commissioner to have and exercise such powers and perform such duties in connection therewith as shall be from time to time prescribed. (Rem.-Bal., secs. 5907-5914, 6604-2-3; Laws 1909, pp. 39; sec. 1, 810-811, sec. 3, 814, sec. 7; Laws 1911, chs. 73, 114; Laws 1913, ch. 164.)

Counties.—The sheriff of each county shall employ all male persons sentenced to imprisonment in the county jail in such manner and at such places within the county as may be directed by the board of county commissioners. Such convicts who shall refuse to perform such labor shall be kept in close confinement on bread and water. The sheriff may, to secure such convicts from escape, attach a ball and chain. Any person convicted of abandonment or neglect of family shall be compelled to work upon the public roads, or any other public work in the county, and the board of county commissioners shall allow and order paid out of the current fund to the wife or guardian or custodian of the child or children at the end of each calendar month for their support $1.50 for each day's work of such prisoner. (Rem.-Bal., secs. 2279, 3895, 5933-2; Laws 1909, ch. 249, sec. 27; Pierce's Code, 1912, p. 115, sec. 213, p. 135, sec. 53.)

WEST VIRGINIA.

State.—Whenever any county court shall have decided to construct or improve a road in accordance with plans and specifications made by the chief road engineer, and shall have agreed in writing with the State road bureau respecting the location, construction, and material, then such county court may apply to the State board of control for convicts to work on such road, stating the number, not less than 10, desired and the length of time they are desired. If the number of prisoners available in the penitentiary will suffice to meet all applications pending, said board shall grant all such that are satisfactory. If the prisoners available are not sufficient to meet all applications, such applications shall be filled in the order of their receipt, but, so far as possible, equal service shall be given to all counties. The board of control, with the warden of the penitentiary, shall determine what prisoners may be assigned to such work, and a written contract shall be entered into between the board of control and the county court. (Acts 1913, ch. 41.)

The State prison road force shall be guarded, while working on the roads of the State, or making road materials, by guards detailed by the warden of the penitentiary, not to exceed two guards to every 20 convicts. At the request of the State road bureau, prisoners may, as far as practicable, be made trusties. The warden shall provide suitable movable quarters, necessary cooking utensils, beds, wagons for transporting convicts, camp fixtures, clothing, and food; provided, that the State road bureau may require any county to pay for food and quarters when working therein on a road chiefly of local importance. All work shall be under the direction and control of the chief road engineer. When a convict shall become sick he shall receive proper attention at expense of the county. Any county desiring convicts under this act shall agree to supply all necessary material, tools, and teams required by the plans and specifications of the chief road engineer. If a convict shall escape he shall receive the same punishment as is provided for escape from the penitentiary. (Acts 1913, ch. 41, secs. 19-25, 28.)

If the local road authorities of any county shall propose to improve any public road with the aid of the chief road engineer and the State convict road force, but shall prefer to have it done by contract, same may be done and convicts furnished at $1 per day in number not to exceed 40 per cent of the total contract price. Convicts so employed shall remain under the supervision and care of the penitentiary warden. (Acts 1913, ch. 141, sec. 27.)

Counties.—Any male person over the age of 16 convicted of an offense punishable by confinement in the county jail shall be sentenced by the court, in its discretion, to work on the public roads under the county road engineer or other official to be designated by the county court. (Acts 1913, ch. 42.)

All male persons over 16 years old, convicted before a justice of the peace of crime and sentenced to imprisonment in county jail or to pay a fine and costs, may be sentenced to hard labor on the public roads. Such convict who shall escape shall be given an additional sentence of not less than 60 days nor more than six months, plus the cost of arrest and trial. The sheriff, with approval of the county court, shall employ necessary guards, not exceeding one for each 10 convicts. Such prisoners who shall faithfully comply with rules and regulations shall be entitled to a deduction from sentence of five days per month. (Acts 1913, ch. 43.)

Persons charged with misdemeanor and awaiting trial in default of bail may, if they elect, be permitted to work on roads in like manner as convicts. Any such person who shall be convicted when tried shall be credited at $1 per day, with such work on his sentence or on fine and costs, and if acquitted he shall receive 50 cents per day for such labor. A deduction of five days per month shall be granted such persons for compliance with rules and regulations. (Acts 1913, ch. 44.)

Jailers shall receive 50 cents per day for keeping and supporting a person confined in the county jail. (Acts 1915, ch. 93.)

WISCONSIN.

State.—The State board of control may employ inmates of the State prison in improving such roads as said board and the State highway commission may determine and in such manner and under such terms as may be agreed upon. For each convict so employed said board shall set aside for such work performed such per diem as shall be deemed proper, said money to be paid either to such convict or to the dependent members of his family. Said board may purchase or lease necessary tools and machinery. (Acts 1913, ch. 717.)

Counties.—In counties having a population of less than 100,000 there may be provided by the county board convenient to the county jail a quantity of stone and appropriate implements for breaking same suitable for road purposes. All able-bodied male persons convicted and sentenced to imprisonment in the county jail shall be employed in breaking such stone not more than eight hours per day. County boards of supervisors may prescribe necessary rules and regulations to govern such work and for the maintenance of such stone and implements. (Wis. Stats. 1911, Title XXXIV, ch. 202.)

WYOMING.

State.—The construction, repair, and maintenance of the system of public highways established by chapter 44, acts of 1911, as amended by chapter 124, acts of 1913, shall be under the authority and control of the State commission on prison labor, who shall construct same and extensions thereto by the labor of convicts obtained from the State penitentiary. Supervision of such work shall be under a competent person selected by said commission, but said convicts shall not be worked more than eight hours any day. Said commission shall adopt rules and regulations providing for the granting of an additional good-time allowance in the case of prisoners serving short sentences and better food for prisoners serving life sentences, conditioned on good behavior and efficient work. The location, surveying, plans, and specifications and the selection of materials for such highways shall be under the direction of the State engineer, the expense for which, including salary of deputy engineer to be furnished by the State engineer, shall be paid by the board of county commissioners of the county or counties in which said work is done. Boards of county commissioners of the several counties through which said public highways pass shall secure the rights of way therefor, and shall build the necessary bridges over any and all rivers over which said highways pass, provided such bridges shall be built in accordance with the plans of the State engineer, and that, as far as practicable, bridges across small streams shall be constructed by said convict labor. Appropriations from the State treasury are made to purchase necessary tools, implements, supplies, and equipment in connection with employing prisoners on public highways, $5,000 being so appropriated for the two years ending March 31, 1917. (Acts 1911, ch. 44, as amended; acts 1915, ch. 162.)

Counties.—All persons sentenced to confinement at hard labor in any jail or prison of any county, city, town, village, or municipality may be employed upon any public work of improvement or upon the highways, streets, alleys, parks, or other public places located therein. (Comp. Stats., 1910, ch. 418, sec. 6401.)

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THE RECOVERY OF POTASH FROM ALUNITE.

By W. H. WAGGAMAN, *Scientist in Fertilizer Investigations*, and J. A. CULLEN, *Analyst*.

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INTRODUCTION.

The scarcity of potassium salts in this country due to disturbed conditions abroad, coupled with the discovery of extensive deposits of high-grade alunite[1] in central Utah, have caused considerable development work in this field and greatly stimulated interest in processes for the extraction of potash from this mineral.

Alunite, even when fairly pure, must be regarded as a relatively low-grade potash carrier, and since the more important deposits occur in a region far from the fertilizer market, any process employed for the extraction of potash from the mineral must be not only highly efficient but extremely cheap. Indeed, under normal conditions it is unlikely that any method will prove commercially practicable for exploiting the Western alunites which does not produce in addition to a soluble potash salt, some other salable product.

Experience in the handling of low-grade ores, or in operations for the extraction of a moderate-priced product from any raw material, has shown that strict attention to details and a knowledge of their importance will often mean the difference between profit and loss.

It was with a view to determining the importance of such details in the recovery of potash from alunite that the work described in this paper was undertaken.

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[1] Butler and Gale, Bull. 511, U. S. Geological Survey (1912). Loughlin, G. F., Bull. 620-K, U. S. Geological Survey (1915).

COMPOSITION AND PROPERTIES OF ALUNITE.

Alunite is a hydrous sulphate of potash and alumina which may be represented by the following formula:

$$K_2O.3Al_2O_3.4SO_3.6H_2O.$$

The percentage composition of the pure mineral, according to Dana,[1] is as follows:

Per cent.
SO_3 =38.60
Al_2O_3=37.00
K_2O =11.40
H_2O =13.00

The mineral usually occurs as a massive, fine-grained, pinkish-white rock breaking with a conchoidal fracture. Some of the coarser varieties are distinctly crystalline in character. While theoretically it should contain over 11 per cent of potash, it is seldom found in minable quantities running over 9.5 or 10 per cent in potash. It is frequently contaminated with quartz and the silicates of potash from which it is derived. The mineral is insoluble in water, but soluble in strong sulphuric acid. On heating to a moderate temperature (500° C.) water is driven off and the mineral decomposes into alumina and potassium aluminum sulphate.[2] Upon increasing the temperature (to 700° to 750° C.) the latter compound is decomposed, fumes of sulphur dioxide and trioxide are evolved, and a residue remains which consists of alumina and soluble potassium sulphate.

GEOLOGICAL OCCURRENCE AND ORIGIN.

Alunite forms seams in trachytic and similar rocks, being produced by the alteration of such rocks by means of sulphurous vapors or sulphate solutions. It is believed to be closely related in origin to metal veins.

Ransome[3] has discussed the various methods by which alunite deposits may be formed, and Butler and Gale[4] quote extensively from the former in their description of a deposit southwest of Marysvale, Utah. The latter authors in discussing the Marysvale alunite state that they consider the main vein in this locality a fissure filling and not a replacement of the wall rock, and cite, as proof of this theory, the fact that the alunite contains but little silica, while in the wall rock where replacement has taken place quartz phenocrysts remain practically unaltered. They conclude that the mineral vein was introduced in part at least by solutions of deep-seated origin.

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[1] System of Mineralogy.

[2] As a matter of fact it is very difficult to drive off the water of constitution without also driving off some of the oxides of sulphur.

[3] Prof. Paper No. 66, U. S. Geological Survey, pp. 189–195 (1899).

[4] Bull. 511, U. S. Geological Survey (1912).

The alunite described by these writers, however, is mainly the pink variety, crystalline or cryptocrystalline, coming chiefly from a large banded vein cutting the volcanic rock at a high elevation about 7 miles southwest of Marysvale. The samples of alunite used in the following experiments were a light colored variety showing little or no crystalline structure and some of it containing considerable amounts of silica. These samples came from two deposits[1] about 10 miles north of that described by Butler and Gale. One appears to be a very wide vein between two rhyolite dikes. The other has the appearance of an enormous outcrop, one wall of rhyolite well defined. The geological features, however, have not as yet been worked out in detail.

LOCATION, EXTENT, AND ACCESSIBILITY OF THE UTAH ALUNITES.

While a number of occurrences of alunite of minor importance have been reported[2] by the United States Geological Survey, the most important deposits described[3] are those occurring in the Tuscar mountain range at the head of Little Cottonwood Canyon from 7 to 8 miles southwest of Marysvale, Piute County, Utah. (See fig. 1.)

The lower end of this deposit is fully 4,000 feet above Marysvale, the present terminus of the San Pete Branch of the Denver & Rio Grande Railroad. This branch connects with the main line of the Denver & Rio Grande at Thistle, about 100 miles north of Marysvale.

Butler and Gale have estimated the amount of high-grade alunite in one group of claims (to a depth of 100 feet) at 300,000 tons. Loughlin[4] in a later examination of some other properties in this region increased this estimate of high-grade alunite to 474,900 tons.

About 2 miles north of Marysvale begins the Sevier Canyon. The Sevier River runs between steep and often sheer banks rising from a few feet to several hundred, the banks being backed by mountains rising in some cases as high as 2,000 feet above the river bed. The canyon is about 14 miles long and on both sides for a distance of 8 or 10 miles north of Marysvale and a distance of 3 or 4 miles on each side of the river it has been very actively if not thoroughly prospected for alunite, a great many locations having been made within the last two years. Some fine masses of the typical pink or pinkish cryptocrystalline varieties have been found, though usually these are so located as to make their exploitation difficult. But a large area of light-colored material has also been discovered, some of which is of

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[1] The geological data and geographical location of the deposits of light-colored alunite were furnished by Dr. F. K. Cameron, formerly of this bureau, to whom the writers are also indebted for a number of valuable suggestions.

[2] Phalen, W. C., Mineral Resources, pp. 9–33, U. S. Geol. Survey (1913).

[3] Butler and Gale, Bull. 511, U. S. Geological Survey (1912). Loughlin, G. F., Bull. 620-K, U. S. Geological Survey (1915).

[4] Bull. 620-K U. S. Geological Survey (1915).

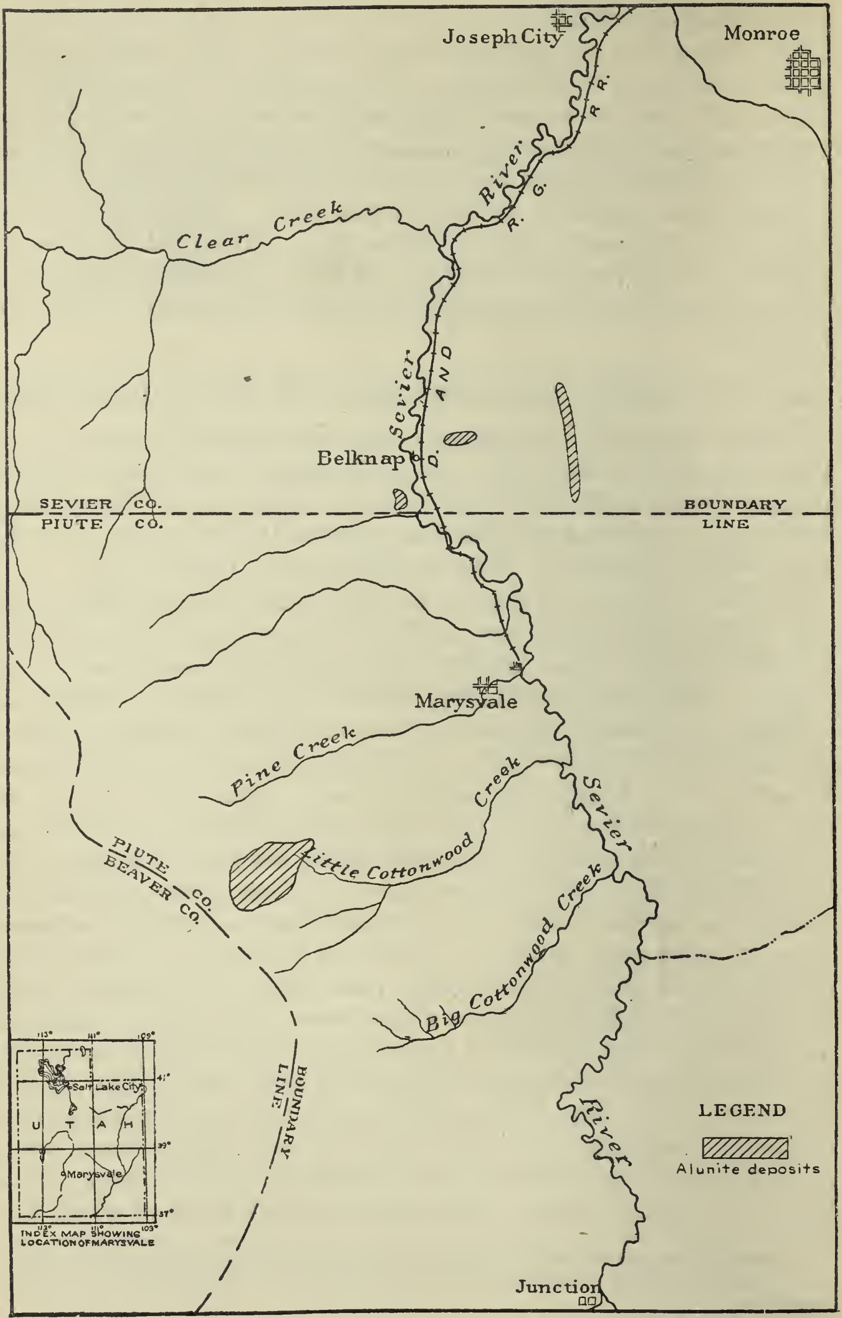

FIG. 1.—Sketch map showing location of alunite deposits near Marysvale Utah.

good grade, and should increase considerably the supply of commercial alunite in sight.

Another important deposit occurs between 4 and 7 miles north of Marysvale and about 3 miles from the river and the station of Belknap, on the Denver and Rio Grande Railroad. The alunite lies between two rhyolite dikes running almost due south from Twin Peaks (better known locally as Peak St. Louis or Iron Mountain) to a peak (Santa Cruz claims) just north of the dividing line between Sevier and Piute Counties. There is a fairly good wagon road from Iron Mountain to Belknap. The alunite mass between these two dikes is from 1,200 to 1,500 feet wide and about 4,000 yards long. While no measurements have actually been made, the depth of the deposit is probably considerable.

These alunite deposits occur at a much lower level and are more readily accessible than the purer crystalline deposits southwest of Marysvale and should be mined and shipped very cheaply.

THE PRODUCTION OF ALUM FROM ALUNITE.

The main commercial use of alunite heretofore has been in the manufacture of potash alum. This industry was introduced into Europe as early as the thirteenth century and assumed considerable prominence at Tolfa, Italy, where extensive deposits of alunite occur. Alum is still produced in this region by the following process:

The mineral is calcined at low red heat in heaps or in kilns for about 6 hours. When the oxides of sulphur begin to escape the material is removed and transferred to brick bins, where it is exposed to the air for several weeks or months, being moistened with water from time to time during that period. The product is then mixed with water and after the insoluble material has settled the clear solution is decanted, evaporated, and crystallized. The reactions taking place on heating to 500° C. may be represented thus:

$$1.\left\{\begin{array}{lllll} \text{Alunite.} & & & & \\ K_2O.3Al_2O_3.4SO_3.6H_2O= & & & & \\ \text{Potass. aluminum sulphate.} & & \text{Alumina.} & & \text{Water.} \\ 2KAl\,(SO_4)_2 & + & 2Al_2O_3 & + & 6H_2O \end{array}\right.$$

$$2.\left\{\begin{array}{lll} \text{Potass. aluminum sulphate.} & & \text{Water.} \\ 2KAl\,(SO_4)_2 & + & 24H_2O= \end{array}\right.$$

$$\begin{array}{c} \text{Potash alum.} \\ 2KAl(SO_4)_2\,24H_2O \end{array}$$

Another method of producing potash alum from alunite, as recommended by Guyot[1] consists in heating the mineral to 800 C.° for three hours. The ignited mass is then treated with the proper quantity of sulphuric acid (30° B.) to convert the alumina present into sulphate. After standing for some time an amount of potassium sulphate is added sufficient to convert the aluminum sulphate into the double salt. The clear liquid is then decanted off and evaporated until the potash alum crystallizes out. The reactions on heating to 800° C. may be represented thus:

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[1] Sur la richesse industrielle de l'alunite cone en poudre. Compt. Rend. Acad. Sci. Paris, *95* pp. 693–694; Experiences sur la calcinations de l'alunite en poudre. Idem. p. 1001–1003.

$$1.\left\{\begin{array}{l}\text{Alunite.}\\ K_2O.3Al_2O_3.4SO_3.6H_2O=\\ \begin{array}{ccccccc}\text{Potassium sulphate.} & & \text{Alumina.} & & \text{Sulphur trioxide.} & & \text{Water.}\\ K_2SO_4 & + & 3Al_2O_3 & + & 3SO_3 & + & 6H_2O\end{array}\end{array}\right.$$

$$2.\left\{\begin{array}{ccccccc}\text{Alumina.} & & \text{Sulphuric acid.} & & \text{Aluminum sulphate.} & & \text{Water.}\\ 3Al_2O_3 & + & 9H_2SO_4 & = & 3Al_2(SO_4)_3 & + & 9H_2O\end{array}\right.$$

$$3.\left\{\begin{array}{l}\begin{array}{ccccc}\text{Aluminum sulphate.} & & \text{Potassium sulphate.} & & \text{Water.}\\ 3Al_2(SO_4)_3 & + & 3K_2\,SO_4 & + & 144H_2O=\end{array}\\ \qquad\qquad\text{Potash alum.}\\ \qquad\qquad 6\,KAl\,(SO_4)_2\,24H_2O\end{array}\right.$$

In the production of alum from the alunite occurring at Bullah Delah, Australia,[1] a process similar to that just described is practiced, but no particular temperature of ignition is specified and the excess of alumina is not converted into alum by the addition of potassium sulphate, since it is considered more profitable to manufacture aluminum sulphate as a by-product and to produce alum equivalent only to the potash present in the alunite. This practice is no doubt the best in localities far removed from other sources of potash.

While it was not the purpose of the present investigation to study details of alum manufacture, it would seem that in regions where another source of potash is readily and cheaply available a combination of the two processes outlined above promises greater possibilities than either of the methods employed at present.

In brief, it is thought that the ignition of alunite at a moderate temperature (500° to 550° C.) and subsequent treatment with sulphuric acid and potassium sulphate would mean a saving both in fuel and in the quantity of acid required to convert all the alumina of the mineral into alum.

THE PRODUCTION OF POTASH FROM ALUNITE.

Besides the processes just outlined for the production of alum six general schemes have been proposed for the utilization of the potash in alunite for other purposes.

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[1] Pittman, E. P. Alunite in New South Wales. Report Geol. Survey New South Wales (1901).

The first of these is the use of the material after ignition at 750° to 800° C. directly as a fertilizer without effecting a separation of the soluble potash salt. It has been pointed out by one of the writers [1] that the material after ignition compares very favorably in regard to its potash content with "manure salt" or other low-grade potash carriers heretofore imported from Germany. If produced in the West, however, it is unlikely that such a low-grade product could stand the cost of the long rail haul necessary to bring it to the fertilizer market. Moreover, no salable by-product would be obtained, except perhaps sulphuric acid, which would require expensive equipment to collect and which under normal conditions has a very restricted market in the West.

The second scheme [2] is to ignite the material at 800° to 1,000° C. till the sulphate of aluminum is decomposed and then leach the residue with hot water to dissolve out the potassium sulphate, which is later recovered by evaporation of the solution. In the case of the purer alunites the residue consists largely of aluminum oxide suitable for the manufacture of metallic aluminum. This method has attracted considerable attention, and it is understood that a procedure similar to, if not identical with, it is being practiced in the western alunite fields. Difficulty in obtaining complete extraction of the potash in the ignited alunite has been experienced both in the laboratory [1] and on a commercial scale, and it was partly with a view to studying the causes of this incomplete recovery of the potash that the experiments described further on were conducted.

The third process [3] consists in roasting alunite with lime at 1,200° to 1,800° F., producing thereby sulphate of lime (gypsum) and potassium sulphate, and rendering the alumina insoluble. The potassium sulphate is then extracted with water. The main purpose of this process is to produce potassium sulphate without causing the evolution of objectionable or injurious fumes of sulphur dioxide and trioxide.

The cost of the lime required, the conversion of the sulphuric acid into a relatively valueless form, and finally the difficulty of separating the resulting gypsum from both the potash and the alumina, render this process of rather doubtful value. As far as is known this process is not at present being employed for the manufacture of potash from alunite.

The fourth [4] process consists in first calcining the alunite to drive off the oxides of sulphur and the water and then increasing the temperature to between 1,100° and 1,600° C., thus volatilizing the potassium sulphate and collecting it in some suitable manner. It is claimed that the addition of carbon to the mineral during ignition facilitates the volatilization of the potash, causing it to take place at a much lower temperature than that specified above. The residue, it is said, is suitable for the manufacture of metallic aluminum.

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[1] Circular 70, Bureau of Soils, U. S. Dept. Agr. (1912).
[2] Chappell, H. F., U. S. Patent No. 1070324 (1913).
[3] Morgan, Geo. S., U. S. Patent 1161239 (1915).
[4] MacDowell, C. H., U. S. Patent No. 1136549 (1915).

Potash is now being recovered as a by-product from blast-furnace operations and in the manufacture of cement from potash-bearing silicates, lime being used to convert the potash into oxide, in which form it is readily driven off. The residue then consists of a clinker having the composition and properties of hydraulic cement, a readily salable product.

While the volatilization process may be applicable to the purer grades of alunite, it seems likely that a fixation and consequent loss of potash would ensue if this practice were applied to alunite high in silica. The addition of coal or coke to the charge, as recommended by the inventor of this process, would also tend to decrease the value of the residue remaining in the furnace.

In order to avoid the difficulty of obtaining a complete extraction of the potash from highly heated alunite, and also for the purpose of obtaining alumina in a pure form suitable for the manufacture of metallic aluminum, Cameron[1] has proposed a process, the first steps of which are similar to the old method of making potash alum. The mineral is first ignited at a relatively low temperature (500° to 550° C.) sufficient only to decompose it into alumina and the double salt potassium aluminum sulphate. The latter compound, which is much more soluble than potassium sulphate, is leached out with water, and alum is crystallized from the resulting solution. The alum is then heated till it decomposes, yielding pure alumina and potassium sulphate, which are separated by solution of the latter. The fumes of sulphur dioxide and trioxide evolved during the decomposition of the alum are conducted into a suspension of the alumina from the first ignition, forming aluminum sulphate and sulphite. The salts in solution are then filtered free from any insoluble residue and either sold directly as precipitants or mordants, or they are evaporated to dryness and ignited to produce more alumina.

Another method of treating alunite has been the subject of a public-service patent application by Mr. Paul J. Fox, of this bureau. In this process the aim is to separate the potassium as sulphate and leave the aluminum as fluoride in a condition suitable for recovery by electrolysis. The sulphuric acid is not recovered. Alunite and fluorspar or some other fluoride are powdered and intimately mixed (or, better, are ground together) and heated at such a temperature that the hydrofluoric acid (of the fluoride) is set free by the sulphuric acid (or sulphur trioxide) yielded by the alunite on heating. The author states that this converts the alumina into aluminum fluoride, the potassium remaining as sulphate. The product is then leached, the potassium dissolving as sulphate, and the aluminum remaining in the residue in large part as fluoride. Considerable calcium sulphate remains with the aluminum fluoride, which might necessitate changes in the standard process for the electrolytic recovery of aluminum.

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[1] An application for a patent on this process has been filed by the inventor.

TEMPERATURE OF IGNITION AND ITS EFFECT ON THE SUBSEQUENT LEACHING OF ALUNITE.

Of the methods so far proposed for the production of potash from alunite, those which depend on simple ignition and subsequent extraction of the soluble potash with water appear to the writers most attractive.

The following investigation was conducted for the purpose of dedetermining the best conditions under which a complete extraction of the potash could be made from impure as well as the purer grades of alunite, with due regard to the production of a salable by-product. The investigation involved the study of the effect of ignition at various temperatures, as well as the influence of fineness of division on the solubility, or, more correctly speaking, the ease with which the mineral yields its potash to hot water.

Chappell,[1] in discussing the ignition of and subsequent extraction of potash from alunite, states that the temperature may be carried over 1,000° C. without causing the formation of potassium aluminate, and recommends a temperature of from 800° to 1,000° C. for alunites containing from 1 to 2 per cent of silica. The experience of the writers has been, as shown below, that in igniting alunite containing even small quantities of silica, 800° C. should be the maximum temperature allowed in the furnace.

Eleven samples of light-colored alunite from the deposits north of Marysvale, Utah, were employed in these experiments. Most of the samples were ground to pass a 100-mesh sieve, though it was later shown that this was probably unnecessary. The material ranged in potash content from 3.48 to 9.61 per cent and in silica from 1.67 to 39.93 per cent.

The potash content of the samples was determined by the J. Lawrence Smith method,[2] and silica and alumina were also determined in all the samples. The results of these analyses are given in Table I.

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[1] U. S. Patent No. 1070324 (1913).

[2] In order to avoid an excess of sulphates, the samples after being weighed out were ignited at a bright red heat before mixing with the ammonium chloride-calcium carbonate mixture.

TABLE I.—*Analyses of samples of light-colored alunite from the Marysvale area, Utah.*

Sample number.	Silica (SiO_2).	Iron and aluminum oxides. (Fe_2O_3, Al_2O_3).	Potash (K_2O).	Sample number.	Silica (SiO_2).	Iron and aluminum oxides (Fe_2O_3, Al_2O_3).	Potash (K_2O).
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	4.41	36.10	9.61	7	39.93	23.17	5.64
2	16.98	35.96	6.13	8	1.67	37.38	8.60
3*b*	16.66	34.30	7.24	9	35.93	25.82	4.30
4	29.14	27.06	6.89	10	39.20	26.97	3.48
5	27.50	28.49	6.13	11	22.08	30.16	6.41
6	5.90	36.71	8.20				

Two-gram samples of each alunite were then heated in an electric muffle furnace for a little over an hour at from 550° to 650° C. and from 850° to 950° C. Four samples (Nos. 1, 2, 5, and 6) were heated to a temperature midway between these two extremes, namely, 750° to 775° C.

The loss on ignition was determined and the residues then washed on the filters with small successive quantities of hot distilled water till the washings gave practically no test for sulphates. The filtrates were then analyzed for potash and the efficiency of the extraction thus determined. The results of these experiments are given in Table II.

TABLE II.—*Loss on ignition and percentage of potash extracted from alunite after heating at various temperatures.*

Sample number.	Loss on ignition at—			Proportion of total K_2O extracted with water after ignition at—		
	550° to 650° C.	750° to 775° C.	850° to 950° C.	550° to 650° C.	750° to 775° C.	850° to 950° C.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	14.50	37.71	39.55	98.44	100.00	89.49
2	20.30	32.37	35.81	97.23	94.78	35.90
3*b*	21.71	....	35.35	93.64	....	59.95
4	15.01	....	29.43	99.28	....	85.20
5	12.44	28.37	31.04	84.99	87.28	54.97
6	22.18	37.55	39.09	91.30	100.00	92.17
7	14.18	....	26.41	94.15	....	55.69
8	16.13	....	41.93	(1)	....	92.44
9	14.26	....	28.55	64.89	....	39.77
10	14.54	....	26.86	[2] 58.62	....	9.50
11	16.71	....	33.00	73.17	....	72.08

[1] Determination lost.

[2] Traces of feldspathic material found in this sample by Mr. W. H. Fry probably explain the low yields of potash on leaching.

A study of Table II will show that the extraction of potash by water from the alunite heated at a relatively low temperature (550° to 650° C.) was much more complete than from those samples heated to 850° C. or above. By referring to Table I it will be seen that the low yield of potash obtained from the highly heated mineral was especially marked in the case of the samples containing large percentages of silica, indicating that at high temperatures a fixation of the soluble potash takes place in the presence of this substance. The leached residues from the highly heated samples, 3*b*, 7, and 10, were, therefore, submitted for a microscopic examination by Mr. W. H. Fry, of this bureau, but owing to the amorphous nature of the material no compounds of silica and potash could be identified.

It is possible also that there might be a loss of potash through volatilization, but analyses of the leached residues 2 and 5 showed there had been no such loss.

In order to leach the highly heated samples free from sulphates only 75 c. c. to 115 c. c. of hot water were required, while the samples heated to 550° to 650° C. required from 280 to 400 c. c. of water. The difficulty in extracting the sulphates in the latter case was due in part no doubt to the gelatinous nature of the residue and partly also to the greater quantities of basic sulphates present. The filtrates from these latter residues were quite cloudy on account of the separation of basic aluminum sulphate, and upon the addition of ammonia considerable alumina was precipitated. The filtrates from the highly heated samples, on the other hand, were only slightly cloudy and contained but very little alumina, showing that the decomposition of the double salt potassium aluminum sulphate was practically complete.

The four samples of alunite (Nos. 1, 2, 5, and 6) which were heated from 750° to 775° C., a temperature only slightly above that at which complete decomposition of alunite takes place,[1] yielded up their potash quite readily, less than 100 c. c. of hot water being required to wash the residues free from sulphates. Moreover, the extraction of potash was more complete than from the same samples heated at either a higher or lower temperature. The filtrates were somewhat opalescent, but gave only a slight precipitate with ammonia, showing that the decomposition of the double salt potassium aluminum sulphate was almost complete.

INFLUENCE OF FINE GRINDING ON THE EXTRACTION OF POTASH FROM ALUNITE.

In factory practice material may be ground so that 80 to 90 per cent will pass a 60-mesh sieve at comparatively small cost, but the grinding of relatively hard rock to a greater degree of fineness than the above not only consumes considerably more time but also increases appreciably the cost of production.

In the extraction of potash from alunite the question has been raised as to the degree of fineness to which the material should be reduced before ignition in order that substantially all of the potash might be subsequently extracted with water. The following experiment was conducted to test this point:

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[1] Circular 70, Bureau of Soils, U. S. Dept. Agr. (1912).

A sample of high-grade alunite containing 10.56 per cent total potash (K_2O) was ground to three different degrees of fineness as follows: 60 to 100 mesh, 100 to 180 mesh, and 180 mesh and finer. Analyses of the separates showed that there was practically no segregation of potash in either the coarse or fine material.

Two-gram samples of each of the separates were weighed out, ignited at 750° to 775° C. for 1 hour, extracted with water, and the potash determined in the filtrates as before. The results of this experiment are given in Table III.

TABLE III.—*Extraction of potash with hot water from a sample of alunite ground to three different degrees of fineness and ignited at from 750° to 775° C. for over 1 hour.*

Sample number.	Degree of fineness.	Total K_2O.	Amount K_2O extracted.	Proportion of total K_2O present.	Amount of water required for extraction.
	Mesh.	*Per cent.*	*Per cent.*	*Per cent.*	
12*a*	60 to 100	10.56	10.25	97.06	160
12*b*	100 to 180	10.56	10.45	98.96	160
12*c*	180 and finer.	10.56	10.33	97.86	227

The figures given in Table III show pretty conclusively that nothing is to be gained by grinding relatively pure alunite finer than 60 mesh before ignition. In fact it was found that the coarser samples decrepitated on ignition to such an extent that three-fourths or more of the residue would pass a 180-mesh sieve.

ECONOMIC CONSIDERATIONS.

While it was not the purpose of the present investigation to enter into details of the cost of separating the several products from alunite, it is thought that a short discussion of some of its economic features together with a brief consideration of the value of the various products and the estimated cost of producing them will prove of interest.

In the extraction of metals from ores or in the manipulation of any raw material occurring far from the market for the product sought it is usually considered better economic practice to concentrate or carry out the necessary manufacturing processes at a point as near as practicable to the source of the raw materials, thus avoiding the cost of shipment on valueless gangue or industrial waste.

In case of the relatively pure alunites of south-central Utah, however, it seems to the writer that the advantage lies the other way, since practically all of the ingredients of alunite (with the exception of the water) have a commercial value in the east, where better facilities for their separation are to be had and whither the mineral may be shipped at the lower rates usually prevailing for raw materials. Probably factories in the Middle West are most favorably situated for the handling of the raw material.

The ignition of the mineral could probably be very economically carried on at one of the sulphuric-acid plants run in connection with the fertilizer factories. The oxides of sulphur evolved during the burning of ore could be turned into the Glover tower of the acid plant and the yield of acid substantially increased at very little cost. Moreover, the potassium sulphate produced could be consumed on the spot in the manufacture of mixed fertilizers.

In Table IV are given the quantities and value (under normal conditions) of the ingredients of alunite (90 per cent pure) and in Table V the estimated cost of separating and preparing these products for the market.

TABLE IV.—*Amount and value (under normal conditions) of products contained in 1 ton (2,000 pounds) of alunite (90 per cent pure).*

	Dollars.
K_2O, 198 pounds, at 4 cents per pound	7.92
H_2SO_4 (50° B.), 1,647 pounds, at $6 per ton[1]	3.44
Al_2O_3, 666 pounds, at $7 per ton[2]	2.33
Total value	13.69

TABLE V.—*Estimated cost of mining, shipping, and extracting the products of alunite.*

	Dollars.
Mining per ton	1.00
Freight to Mississippi River, per ton[3]	9.00
Cost of grinding, per ton	.30
Cost of ignition, per ton	.50
Cost of acid recovery, per ton	1.00
Cost of leaching and recovering potash	1.00
Total cost	12.80

From the figures given in Tables IV and V it is evident that in normal times the margin of profit on the products of alunite would be extremely narrow because of the long freight haul unless a lower freight rate should be established for the raw material. Under present conditions, however, the prices of metallic aluminum, sulphuric acid, and potash salts have advanced so enormously that the immediate exploitation of the western alunite should prove both practicable and profitable.

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[1] Only three-fourths of the SO_3 of alunite is volatilized on ignition.

[2] The value of the Al_2O_3 is based on that in bauxite. The average bauxite contains 60 per cent Al_2O_3 and is valued normally at $4.75 per long ton.

[3] No commodity rate yet exists for alunite, but if a rate is established it has been estimated that it probably would be in the neighborhood of $9 per ton.

SUMMARY.

Considerable interest is being evinced in processes for the recovery of potash and other products from alunite. This mineral is a hydrous sulphate of potash and alumina. It occurs in important deposits both north and southwest of Marysvale, Utah.

Difficulty in effecting a complete separation of the potash after the ignition of the mineral has been experienced both in the laboratory and in factory practice; and since the material must be regarded as a relatively low-grade potash carrier, cheapness and efficiency in the extraction of the potash are essential to its successful commercial development.

Eleven samples of light-colored alunite from the undeveloped, but readily accessible, area north of Marysvale were ignited at different temperatures and the residues subsequently leached with water. A temperature between 750° and 800° C. was found to be best for the complete extraction of the potash with the minimum amount of water. Temperatures above 800° C. caused a fixation of the potash, particularly where the samples contained much silica.

An experiment to test the influence of fineness of grinding on the subsequent extraction of potash from alunite showed that nothing is to be gained by grinding the material finer than 60 mesh.

Since practically all of the constituents of high-grade alunite have their market in the East, it is suggested that it would prove more economical to ship the mineral East, taking advantage of the lower freight rate on raw material, than to manufacture the finished products near the mines. The freight charges, even then, however, are so great as to leave a very narrow margin of profit on the products in normal times.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 416

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER. January 29, 1917

THE RED SPIDER ON COTTON.

By E. A. McGregor and F. L. McDonough,

Scientific Assistants, Southern Field Crop Insect Investigations.

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The common red spider, *Tetranychus bimaculatus* Harvey, is very generally distributed in the United States. The map (fig. 1), which contains 297 records of occurrence in 34 States, shows the distribution of the majority of reported cases.

The species first became conspicuous as a pest to cultivated crops in New England and the Northeast. The early complaints related largely to greenhouse and dooryard plants, and it was not until 1855 that Glover reported some injury to cotton by the pest. As settlement moved westward, records of occurrence from the Middle West and, finally, the Pacific Slope, appeared in our literature. With the exception of an outbreak in Louisiana, reported by Prof. H. A. Morgan in 1893, severe occurrence of the red spider on cotton had not been reported until 1903, at which time complaints of damage came from South Carolina and Georgia. In 1904 Mr. E. S. G. Titus (1905, *a*, *b*), then of this bureau, found severe infestation in fields about Batesburg, S. C., and the following year he reported severe injury in North Carolina, South Carolina, Georgia, and Alabama. Since then the additional records of Dr. F. H. Chittenden and Messrs. G. P. Weldon, D. T. Fullaway, E. L. Worsham, H. F. Wilson,

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NOTE.—This bulletin is of interest to those who are subjected to loss or annoyance by the red spider.

W. B. Parker, H. E. Ewing, and others, as well as the writers, have established the presence of the red spider from Maine to Florida and westward to Texas, California, and the Hawaiian Islands. It is said to be generally distributed in New England, New York, Iowa, Illinois, the southern parts of Wisconsin and Michigan, western Colorado, the Willamette Valley of Oregon, and the interior regions and southern part of California.

ZONAL DISTRIBUTION IN THE SOUTHEAST.

In the course of our work on distribution it early became evident that the majority of the occurrences in the Southeast were confined to a zone the outer margin of which lies from 60 to 80 miles from the coast and whose inner margin is from 200 miles (along the Atlantic coast) to 275 miles (along the Gulf coast) inland (fig. 1). In general this zone coincides with the portion of the Piedmont Plateau possessing clay or sandy loam soil and excludes the coastal strip of sandy soil. The infested area includes the central belt of oak, hickory, and longleaf pine hills, the sandhills belt, and the granite and metamorphic gray and red lands. The coastal free area includes the marshes, swamps, and live-oak lands of the coast and the longleaf pine flats and savannas near the coast. Whether this restricted distribution is due to the diversity of plant life or to the differences in climatic conditions prevailing in the respective regions it is difficult to determine. Considering the great adaptability of the red spider to hosts, it would appear that the matter of the host flora must be one of minor influence. The material difference in humidity,

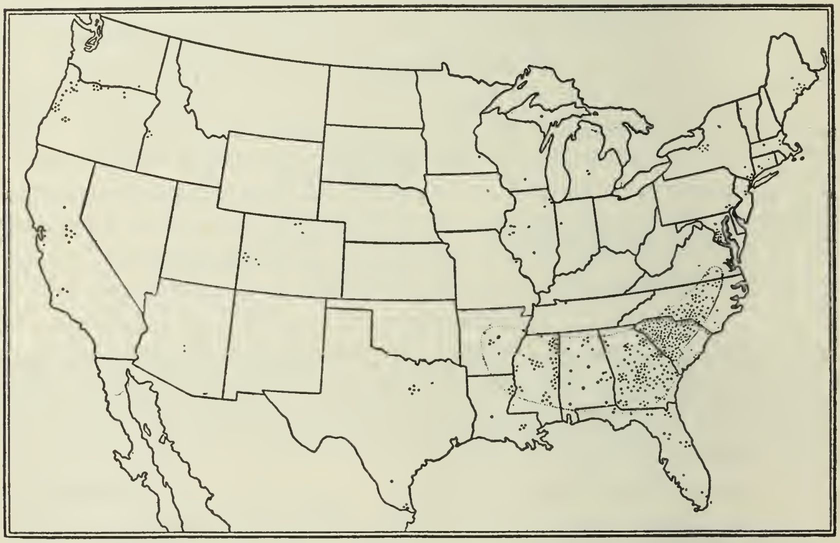

FIG. 1.—Distribution of the common red spider. Large dots represent specific occurrences; dotted line incloses the zone of heaviest occurrence in the Southeast. (Original.)

rainfall, and temperature between these coastal and inland zones probably explains the restriction of occurrence.

CLASSIFICATION AND SYNONYMY.

Owing to the extreme minuteness of red spiders generally, to marked variations due to age, host plant, environment, or other causes, and to the microscopic characters which are employed in the taxonomic treatment of the group, the spinning mites have afforded much speculation among specialists and have caused considerable duplication and confusion of names.

Ewing has published his opinion that *T. bimaculatus* Harvey, *T. sexmaculatus* Riley, and *T. gloveri* Banks are identical with *T. telarius*. The final settlement of this question will be possible only after a careful comparative study has been made of material collected from the localities and hosts recorded for the respective European species. The following list represents the synonymy of the original European red spider (*T. telarius*) as claimed by various workers since Linnæus, chiefly for the purpose of indicating the present confusion in the group.

Tetranychus telarius L.

1761. *Acarus telarius* L.; 1804, *Trombidium t.* Herm.; 1834, *Tetranychus t.* Dugès.
1804. *Trombidium tiliarium* Herm.; 1834, *Tetranychus t.* Dugès; 1867, *Acarus t.* Turpin; 1875, *Tetranychus t.* Koch.
1804. *Trombidium maius* Herm.; 1834, *Tetranychus m.* Dugès.
1804. *Trombidium tenuipes* Herm.; 1834, *Tetranychus t.* Dugès.
1804. *Trombidium socium* Herm.; 1867, *Acarus s.* Muller; 1875, *Tetranychus socius* Koch.
1832. *Tetranychus lintearius* Dufour; 1867, *Acarus l.* Boisduval; 1877, *Tetranychus l.* Murray.
1867. *Acarus russulus* Boisduval; 1875, *Tetranychus r.* Koch.
1867. *Acarus tini* Boisduval; 1877, *Tetranychus t.* Murray.
1867. *Acarus cucumeris* Boisduval; 1877, *Tetranychus c.* Murray.
1867. *Acarus rosarum* Boisduval; 1877, *Tetranychus r.* Murray.
1867. *Acarus cinnabarinus* Boisduval; 1877, *Tetranychus telarius* var. *c.* Murray.
1867. *Acarus haematodes* Boisduval; 1877, *Tetranychus telarius* var. *h.* Murray.
1867. *Acarus vitis* Boisduval; 1877, *Tetranychus v.* Murray.
1867. *Tetranychus ferrugineus* Boisduval.
1875. *Tetranychus urticae* Koch.
1875. *Tetranychus fervidus* Koch.
1875. *Tetranychus populi* Koch.
1875. *Tetranychus piger* Donnadieu.
1875. *Tetranychus minor* Donnadieu.
1875. *Tetranychus longitarsis* Donnadieu.
1875. *Tetranychus plumistoma* Donnadieu.
1875. *Tetranychus rubescens* Donnadieu.
1875. *Phytocoptes epidermi* Donnadieu.
1875. *Phytocoptes gallarum* Donnadieu.
1875. *Phytocoptes nervorum* Donnadieu.
1876. *Tetranychus pilosus* C. and F.
1890. *Tetranychus 6-maculatus* Riley.
1892. *Tetranychus bimaculatus* Harvey.
1900. *Tetranychus gloveri* Banks.

FOOD PLANTS.

As the result of the investigations at Batesburg, S. C., supplemented by observations throughout the cotton belt, this mite has been taken from 183 species of plants, including weeds, ornamentals, and garden and field crops. Upon most of these the pest has been seen only occasionally, but it is found commonly throughout the active season upon the following plants: Cotton (*Gossypium* spp.), cultivated violet (*Viola* spp.), (Pl. IV, fig. 4), Jerusalem oak (*Chenopodium botrys*), wild blackberry (*Rubus* spp.), wild geranium (*Geranium* spp.), ironweed (*Sida rhombifolia*), garden bean (*Phaseolus* spp.), pokeweed (*Phytolacca americana*), tomato (*Lycopersicon lycopersicon*), dahlia (*Dahlia* spp.), (Pl. IV, fig. 3), sweet pea (*Lathyrus odoratus*), (Pl. IV, fig. 5), and hollyhock (*Althaea rosea*).

Of these 183 host plants, 100 (or 55 per cent) are cultivated species and 83 (or 45 per cent) are native wild species. It should be stated, however, that in the preparation of this host list more time was devoted to house yards than to rural localities. It seems reasonable to suppose, therefore, that the common red spider occurs on fully as many wild plants as on cultivated species. The fact that Harvey's (1892) 37 host plants reported from New England, and Ewing's (1914) 30 hosts from the Northwest are practically all cultivated species may be accounted for by presuming that these investigators did not extend their research to the wild plants.

Throughout the past five years of the red-spider investigation it has been brought to our attention repeatedly that certain plants possess a peculiar importance due to their restriction to certain seasons; hence they may thus form a series of links in the cycle of infestation.

The cultivated violet, which has come to be recognized as perhaps the most important wintering host, and as a source of dispersion to neighboring weeds and near-by cotton in the spring, is probably the most commonly infested plant in the South.

The pokeweed (*Phytolacca americana*) occupies an important position as a host, but its exact status has never been clearly determined. Among farmers in various parts of the cotton belt there is a strong belief that red-spider infestation, called by them "rust," has its origin in pokeweed. The result of much careful study during the winter and early spring months seems to refute the idea that pokeweed normally supports mites during these periods. It does, however, function as a very desirable secondary host during the early season migratory movements of the mites by intercepting a few individuals. These intercepted mites multiply rapidly, until the pokeweed no longer furnishes sufficient nourishment, and at such times the infestation spreads to cotton if it is available. (Pl. V, fig. 6.)

Native blackberry vines also constitute an important overwintering host, since many of the leaves remain attached throughout the winter (in the Southeast) and it is usually an easy matter to find red spiders actively feeding on these leaves. Such occurrences give rise to the opinion that much of the infestation in rural localities arises from the wild blackberry.

Several early vernal plants or weeds (escapes) play an important rôle in the seasonal development and spread of the red spider. The more important of these are hedge nettle (*Stachys arvensis*), wild geranium (*Geranium carolinianum*), sow thistle (*Sonchus asper*), evening primrose (*Oenothera laciniata*), sunflower (*Helianthus annuus*), and vetch (*Vicia sativa*). During March and April these plants are usually to be found in beds and borders in sheltered positions and the seasonal development of the red spider progresses faster than elsewhere, owing to the higher temperatures which obtain in these locations. Such beds are prolific dispersion sources.

Garden beans are also important hosts, and throughout June, July, and August are seldom free from mites, at times becoming so heavily infested that their color turns yellow and many of the leaves fall. They are thus a constant menace to surrounding crops.

Tomato vines are known to afford an opportune shelter for mites, and after the abundant appearance of enemies of the red spider, at a time when other infested plants have become cleared of mites, tomato leaves may usually be found to harbor large numbers. This doubtless comes about through the fact that tomato vines rarely support enemies of the red spider. Hence they serve to harbor the mites during periods of heavy mortality until the time arrives when the latter may spread with impunity to other hosts.

Since 1855, when Glover reported injury to cotton by a red spider, Prof. H. A. Morgan (1897), Mr. E. S. G. Titus (1905, *a*, *b*), and other investigators have published on the damage to cotton by this pest. As indicating the very general occurrence of the mite on cotton, it is of interest that in the course of visits to many points in sections of every cotton State, the common red spider was found in every single locality. The majority of these records on cotton concern very light outbreaks.

LIFE-HISTORY SUMMARY.

The eggs of the red spider are deposited on the under surface of leaves of a great variety of plants. The eggs hatch in a few days and the 6-legged larvæ at once begin to feed by inserting their sharp probosces into the tissue of the leaf. The larval activities are confined to the immediate region of birth, and the larvæ soon molt into 8-legged nymphs. Females require two nymphal stages before becoming adult, while males require only a single nymphal stage between the larva and the adult. The female protonymph, like the larva, after a period about equal to that required by the latter, molts to the secondary nymph or deutonymph. The activities of the deutonymph are very similar to those of the protonymph and the duration of the stage is about equal to the time required by the latter. The third molt gives issue to the female. The single nymphal stage of the male exhibits the same biologic activities as do nymphs of the female. The time required for this stage, however, is a trifle longer than that consumed by the female primary nymphal stage, yet slightly shorter than the combined periods of the two nymphal stages. In summer the female requires, usually, about 10 or 11 days for the completion of a generation, while the male requires about 9 or 10 days.

During the course of the year, in the latitude of Batesburg, S. C., there are ordinarily 16 or 17 generations, whereas in cooler portions of the United States, naturally, there are fewer broods. In the South the red spider passes the winter chiefly in the adult stage, and even propagates considerably at a temperature slightly above freezing. Feeding continues intermittently on several species of plants which bear leaves throughout the winter season.

DESCRIPTION AND HABITS.

THE EGG.

Description.—The eggs (Pl. II, fig. 1) are almost perfect spheres. When first deposited they are about as clear as water, but as incubation progresses they become opaque, turning a dark straw color just before hatching. A series of spots becomes apparent, and in the later stages of incubation the carmine eyes of the embryo are visible through the shell. The eggs are deposited singly on the underside of the host leaf and directly on the surface unless copious webbing is present, in which case eggs are frequently attached to the fibrils slightly above the surface of the leaves. Although very minute in size, the eggs are relatively large as compared with the size of the female red spider. A series of measured eggs averaged 0.129 mm. in diameter.

Number laid.—The number of eggs deposited by a single female is subject to considerable variation, depending, apparently, on temperature, locality, and suitability of food, but observations show that practically all of the eggs hatch. Perkins in 1896 states that in Vermont the brood varies between 50 and 100 eggs, that oviposition covers on an average about 7 days, and that the average daily deposition is about 10 eggs. Worsham (1910) records 80 eggs as the average full brood in Georgia, with the daily deposition varying from 1 to 12 per day, and covering an oviposition period of from 6 to 10 days. He states that 94 eggs was the largest number recorded from a single female. Ewing (1914), working in Oregon, found that females averaged 41 eggs per brood, with 63 as the greatest number. His records show 9 eggs as the maximum deposition per day, with 1 as a minimum, and he found that this fluctuation was induced largely by temperature and nutrition conditions.

In the course of the five seasons' observations at Batesburg many colonies have been reared under control. From a series of 90 such broods the summaries given in Table I are derived:

Table I.—*Records of oviposition of the red spider.*

Largest brood	110
Average for 20 largest broods	68.01
Average for 10 largest broods	80.10
High daily depositions 12,[1] 13,[2] 14,[3] 15,[4] 16,[5] 17,[5] 19.[1]	
Maximum daily oviposition	19
Total eggs from 38 broods	1,893
Total egg-laying days (38 broods)	320
Average eggs per day per female	5.92
Average ovipositing days per female	14
Maximum ovipositing days per female	36

From these rearings it follows that for South Carolina the female under proper conditions will produce a brood of from 75 to 110, probably averaging about 85, and that the eggs are deposited usually in from 10 to 12 days at the rate of from 8 to 14 per day.

Incubation period.—The duration of the incubation period varies largely with the temperature in the different localities. Perkins (1897) found that 7 days were required in Vermont for this period. Ewing (1914) states that an average of 5.5 days were consumed at Corvallis, Oreg., between deposition and hatching. In Georgia from 3 to 4 days were required for incubation, according to Worsham. In a series of 71 breeding-cell tests (each cell containing the progeny of 1 female) the average duration of this period at Batesburg was found to be 3.93 days during May, June, July, August, and September.

In hatching, the shell splits more or less completely around and the larva easily extricates itself. During severe occurrences of infestation the leaves of the host plant may be seen thickly covered with the bleached and empty eggshells, which disclose the cause of death of leaves long after the disappearance of the pest has occurred.

The effect of temperature upon the incubation of the red-spider egg is very marked. In midsummer, at Batesburg, with mean daily temperatures between 80° and 90° F., incubation rarely requires more than 4 days. One rearing beginning March 12 consumed 15 days for the hatching period. Eggs, in one case, deposited November 16 hatched in 23 days. During December, January, and February eggs may remain dormant for from 1 to 3 months, hatching with the advent of sufficiently mild weather. The relationship between mean temperatures and the length of the egg period is shown in Table II and figure 2. The eggs of a colony are usually clustered upon the leaf surface or among the fibrils of the webbing and rarely involve an area greater in size than that of a dime.

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[1] 3 cases. [2] 5 cases. [3] 4 cases. [4] 2 cases. [5] 1 case.

TABLE II.—*Duration of the egg stage of the red spider.*

Brood.	Average date of deposition.	Average date of hatching.	Average duration.	Mean temperature for period.
			Days.	° *F.*
1......	Mar. 12	Mar. 27	15.0	54
2......	Mar. 24	Apr. 4	11.5	58
3......	Apr. 4	Apr. 13	10.0	60
4......	Apr. 27	May 3	6.0	67
5......	May 19	May 23	4.0	75.2
6......	June 10	June 13	4.0	81
7......	July 16	July 19	3.5	80.7
8......	Aug. 20	Aug. 23	4.0	79.8
9......	Sept. 2	Sept. 5	4.0	78.9
10.....	Sept. 11	Sept. 18	8.0	69
11.....	Sept. 14	Sept. 19	6.0	70.5
12.....	Sept. 30	Oct. 7	8.0	68.3
13.....	Oct. 31	Nov. 16	17.0	58.9

THE LARVA.

Description.—The newly hatched larva (Pl. II, fig. 2) is round, colorless, and 6-legged, and its body does not exceed that of the egg in size. The two portions of the body, cephalothorax and abdomen, are rather distinctly marked at this time by a transverse suture. The most conspicuous feature of the newly-hatched larva is its bright carmine eyes. It begins feeding at once, and as feeding progresses the larval color deepens to a green or ferruginous green. A characteristic feature of the larva is the shortness of the legs due to inflation of the slightly hardened leg segments. Although the tarsus and the femur are the longest joints of the larval legs, there is no

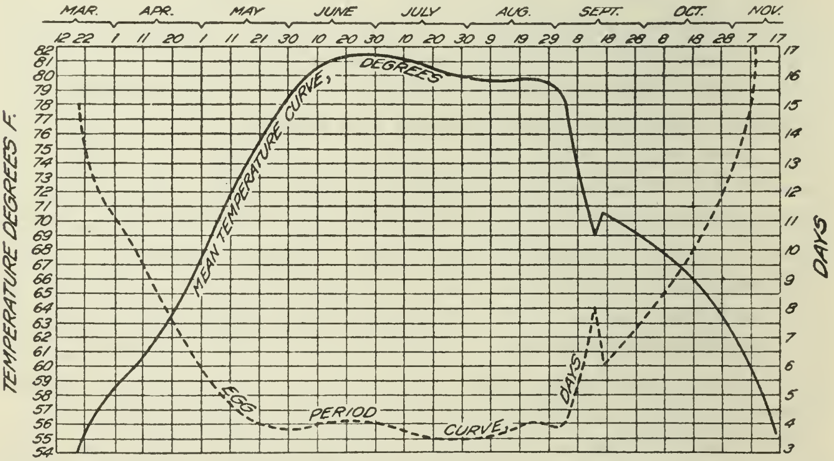

FIG. 2.—Simultaneous curves of temperature and incubation of the red spider, showing the intimate relation between prevailing temperature and the time required for the development of the egg. (Original.)

material difference in the length of the joints such as develops in the later stages. The patellæ and tibiæ are only slightly longer than wide. The onychium, which in the adult becomes conspicuously attenuated, appears as a mere abrupt narrowing of the tarsus in the larva. The larval palpal characters agree very closely with those of the adult, except that the terminal "finger" of the "thumb" seems relatively more slender. The larval body bristles are proportionally shorter and stouter than in the adult. A large series of measurements of larvæ give the following dimensions: Length, 0.151 mm.; width, 0.116 mm.

Length of larval instar.—The time required for the completion of the larval stage is subject to considerable variation, mainly attributable to temperature and moisture conditions. The larva is much less resistant to adverse minimum temperatures than the egg. While in summer this stage rarely requires more than 2 days, in the early spring and late fall records as long as 15, 16, and 17 days are frequently obtained. From data derived from 61 colonies we have computed the average interval between hatching and the first molt to be 1.94 days. Basing his computations on 6 completed records, Ewing (1914) states that the average larval period at Corvallis, Oreg., is 3.33 days. Perkins (1897) found 4 days to be the average time required in Vermont for the completion of this stage.

As has been recorded by a few other workers, the larval stage (as well as the nymphal stages) exhibits an active period and a resting period. The resting stage in South Carolina requires but a few hours for its completion. In 1898 Von Hanstein designated this resting stage by the term "Nymphochrysallis," which he states lasted from 24 to 30 hours at Berlin.

Molting.—The five cases of molting observed occupied from 2 minutes to 4 minutes 20 seconds. The operation is initiated by a brief series of struggles which result in the partial rupture of the skin at the line of the postcephalothoracic suture. The separation is complete over the back and extends laterally down either side, so that the two halves of the old skin are merely connected by a ventral strip. The primary nymph disengages its forelegs and anterior portion of the body. This accomplished, the free legs are used to pull with, and by means of a twisting, wriggling movement the nymph extricates legs III and IV and walks out over the front portion of the cast skin and is entirely free. The exuvium, as a rule, is left *in situ*. The fourth pair of legs, which become evident with the completion of the larval molt, at first appear atrophied and useless, but in a very few minutes the nymph acquires use of its new appendages.

FIRST NYMPHAL STAGE (THE PROTONYMPH).

As has been stated previously, it is only the female which passes through a second nymphal stage.

Description.—The primary nymph (Pl. II, fig. 3) differs from the larva in having 4 pairs instead of 3 pairs of legs, in the somewhat increased size, and in the more oval outline of the body. Furthermore, the bristles are slightly longer, and the segments of the legs become elongated in proportion to their width. The color of the protonymph is usually darker than that of the preceding stage and the lateral pigment blotches become more evident in this stage. One of the most noticeable modifications in the primary nymph is the considerable elongation of the abdomen, the suture separating the latter from the cephalothorax lying in a position slightly more than one-third the body length from the anterior margin of the cephalothorax, whereas in the larva the suture nearly bisects the body. A series of measurements of the protonymph averaged, length, 0.213 mm.; width, 0.145 mm.

The habits of the primary nymph are similar to those of the larva. It moves about more freely than the larva. Investigators of red spiders have claimed that the ability to spin webbing appears for the first time in the protonymph, but no effort has been made to establish this point.

"*Premolting*" *period.*—Perkins (1897) makes no mention of a quiescent period preceding the molting of the primary nymph. Ewing's life-history table shows an average duration of 1$\frac{3}{5}$ days for the resting period before the molting of this stage. At Batesburg the "premolting" period of the protonymph occupies a very few hours. During these quiescent periods the body assumes a pearly or silvery appearance. Von Hanstein (1902) called this quiescent period of the primary nymph the "Deutochrysallis."

Duration of the protonymphal period.—With the records of 6 individuals upon which to base his conclusions, Ewing found that in Oregon the protonymphal stage required from 2 to 4 days, with an average of 3.16 days. At Batesburg 37 colonies completed the primary nymphal stage. In March, in one case, this stage required 6 days for completion, but in the summer the period is occasionally concluded in 1.5 days. The average duration of the female protonymphal stage for all records at Batesburg is 2.18 days.

Molting process.—Of all the red-spider stages, those which are distinguished with the greatest difficulty are the primary and secondary nymphs of the female. It is natural to presume, therefore, that no radical changes occur in connection with the molting process, and this is borne out by observations. The time required was slightly over 3 minutes in the case of the one operation observed. (See fig. 3 for the cast skin of the protonymph.)

SECOND NYMPHAL STAGE (THE DEUTONYMPH).

Description.—The deutonymph, which occurs only in the case of the female, resembles the protonymph except that it is larger and more elongate. In the advanced condition of this stage (Pl. II, fig. 4) it also resembles the adult female. Although pigmentation is intensified as the mite approaches maturity, there is usually an absence of the characteristic reddish color. As the deutonymph approaches maturity it can be distinguished from the maturing male nymph, as the latter is smaller, more cuneate posteriorly, and exhibits a tinge of amber or ferruginous. A series of measured deutonymphs averaged, length, 0.360 mm.; width, 0.218 mm.

Duration of the deutonymphal period.—Perkins (1897) found that in Vermont an average of 2 days was required for the completion of the second nymphal stage under summer conditions. Ewing's 5 completed deutonymphal breedings averaged 2.6 days. The portion of this interval occupied by the quiescent period (the "Teleiochrysallis" of von Hanstein) is not clearly indicated in Ewing's bulletin, but appears to be approximately 1 day.

In the Batesburg investigations 25 colonies completed the second nymphal stage of the female. One deutonymph, the egg of which was deposited on September 27, required 13 days for its development. Exhibiting the other extreme, a few individuals of this stage matured in approximately 1.25 days in midsummer. The average duration for the second nymphal stage during the active season is 1.9 days.

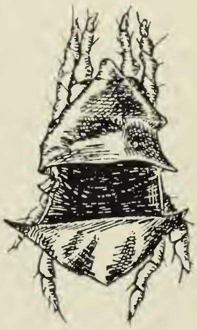

FIG. 3.—Cast skin of the red spider shed at the time of second molt, still united by the ventral tissue. (Original.)

Habits.—The deutonymph is probably the most voracious of the immature mites. It roves about considerably on its native leaf. Ewing (1914) records a well developed spinning ability on the part of the deutonymph. The first two stages are not adapted to traveling over the soil surface, owing to their frailty, but the last immature state is more hardy and active, and individuals are often capable of successfully establishing themselves after traversing considerable distances. This fact has been determined by "tanglefoot" tests, and by finding deutonymphs on cotton seedlings which were younger than the mites.

Molting process.—Upon two occasions, in the early morning, females issued from the second nymphal skin. The transverse split occurs practically as in the two preceding molts. In one instance, following a night minimum of 46° F., the morning was cool, and this condition doubtless worked to retard the duration of the process, which occupied nearly 4 minutes. The other observed molt took place on a warm morning and required less than 3 minutes for its completion. The male has been seen to assist in the molting of the female deutonymph. The attending male, following the transverse splitting of the skin, inserted his palpi, on one occasion, under the old skin, and forcibly pulled it over the end of the female's abdomen.

THE ADULT.

Description of Female (Pl. II, fig. 5).

Color variable; at times rusty green, sometimes greenish amber, or yellowish, at times almost black, but more often brick red or ferruginous red. Pigmented blotches occur almost invariably on the sides of the body, which are usually coalesced to form two large dark spots, one on each side extending from the back of the cephalothorax to the posterior region of the abdomen. These are often interrupted posteriorly to form a large anterior and a small posterior spot. These spots arise from underlying paired organs. Almost directly over coxæ II are the carmine eyespots located on each side, near the margin of the cephalothorax. Legs pale amber, much paler than ground color of body. Palpi pale salmon. Dorsal bristles pale, not arising from tubercles. Body pyriform oval, widest across posterior region of cephalothorax; bristles in four rows, each succeeding pair becoming shorter; the frontal pair a little over half as long as the subfrontal pair, which, like the median pair next behind, are two-fifths the greatest width of body. Mandibular plate about twice as long as broad, tapering slightly forward, broadly rounded at tip, with a slight median notch. "Thumb" of palpus in shape somewhat like a truncated cone, the dorsal face about one-third longer than greatest width at base, the upper surface twice slightly depressed transversely, with an intervening dilation, bearing on its tip a subcylindrical "finger" which is about two-fifths as wide at its base as the distal end of the "thumb." On its upper side, just above the "finger," are two stout, straight hairs arising close together, one medially and the other laterally, which do not greatly exceed in length the "finger." Near the middle of the upper side is a smaller "finger" three-fourths the length and one-half the width of the terminal "finger" and very similar to the latter. Between this dorsal "finger" and the base of the "thumb" are 2 strong, curved hairs about equaling those at tip of "thumb," and at middle of latero-ventral aspect of "thumb" arises a hair about equaling the latter. The penultimate palpal joint bears the usual claw, which reaches about to the basal "finger," and also bears 2 bristles, one arising dorsally at base of claw which hardly equals the length of claw, and one arising near center of outer side which about equals the dorsal bristle. Legs I hardly equal the length of body from the anterior margin of cephalothorax to tip of abdomen; relative lengths of segments of leg I, coxa 25, trochanter 15, femur 53, patella 23, tibia 30, tarsus 49; femur almost 4 times as long as thick; tip of tarsus (the onychium) bearing a claw which is strongly arcuate and 4-cleft to its middle. Arising also from the onychium, laterad of base of claw on either side is an enlarged process which immediately splits into 2 nearly straight hairs, each of which bears a capitate tip. These 4 capitate hairs spread spokelike in the same plane and their relative lengths are similar to those of the fingers of the human hand viewed from the top. The location of bristles near the onychium is not constant, varying with the locality, etc., 1, 2, or 3 hairs occurring at the point of abrupt enlargement near the tarsal end which reach almost to the tips of the capitate hairs, and 2, 3, or 4 hairs occurring at a distance from the onychium about twice as great as that of the distal hairs. (Pl. III, figs. 13, 14.) A series of measured females gave the following dimensions: Length (front of cephalothorax to tip of abdomen), 0.424 mm.; width (across posterior margin of cephalothorax), 0.278 mm.; length of foreleg, 0.325 mm.

Longevity.—The duration of life of the adult female may be divided into two periods—a short period immediately following the deutonymphal molt during which no eggs are laid, and a rather extended egg-laying period, which, as determined by experiments at Batesburg, is 18.8 days. Perkins states that in warm, dry weather the female begins to oviposit in about 48 hours after the last molt, and that in cooler weather egg laying may not begin for several days. Von Hanstein (1901) found the preoviposition period of *Tetranychus althaea* to be eight days or more. Ewing (1914) records the average duration of the period previous to egg laying to be three and four-fifths days. During this inactive period the female mates, feeds to some extent, and exhibits a desire to migrate.

The adult life, from the last molt to death, as computed from 23 females, is 12.43 days for the summer season in South Carolina. The longest individual record of longevity at Batesburg is 39 days, covering a period from September 1 to October 9, most of which was during warm weather. The next longest record was 23 days, covering a period from September 1 to September 24, also during warm weather. Perkins states that in Vermont the females under favorable conditions may live at least three weeks and probably longer. Ewing found the average longevity of the female during the early fall in Oregon to be 21⅓ days. Morgan (1897) claimed that females live only from five to seven days after reaching maturity. The virile late-fall female often lives five months. Very little is known concerning the longevity of the male.

Color variations.—That red spiders vary in color has been observed for a long time. It was observed in the case of the European species, and seems to have been instrumental largely in the formation of numerous synonyms by early writers. For a long time it was held that this diversity in color was due mainly to the varying nature of the host plants.

Ewing (1914) conducted a series of experiments for the purpose of ascertaining the nature, situation, and composition of what he styles the six principal pigments of the common red spider, namely, green, yellow, orange, carmine, black, and brown. In summarizing he states that the green color is due to the presence of chlorophyll in the blood or tissues of the mites; that the yellow color arises from a pigment derived from and closely allied to the chlorophyll green pigment and which is elaborated from the green pigment; that the orange color is due to a pigment of that color which is dissolved in the cell fluids or the blood and is quite permanent, is unaffected by age, and is never found except in adults on certain hosts; that the blackish color does not arise from a distinct pigment, but is due to the concentration of the yellow pigment in the food material; that the brown color also is due to a superabundance of the yellow pigment; and, finally, that the carmine of the region of the eyes is due to the presence of a permanent pigment which is present even before hatching. Ewing states that in his experience reddish individuals are exceptional. The experiments conducted by Ewing are a distinct step in advance and, it is hoped, will stimulate additional research in that direction. Perkins was of the opinion that dark-colored females are ones that have been impregnated, and that light-colored females are weak sexually and have either no offspring or impotent progeny.

As a rule the females we have observed are either brick-red, orange, amber-yellow, greenish, or brownish-green. During the period from April to September, inclusive, the vast majority of adult females in the South are a conspicuous brick-red color. Toward late fall the females often assume a salmon-yellow color in the Southeast. Von Hanstein (1902) also found this to be the case in Europe with *T. althaea*, and he considered that the color was associated with preparation for wintering. It certainly is very striking that the red type of female almost disappears in the fall and is replaced by the orange-yellow type.

DESCRIPTION OF MALE.

The color of the male is rusty salmon; the lateral spots are less conspicuous and usually located near the front of the abdomen; the cephalothorax is often nearly clear straw color. Eyes crimson, relatively more conspicuous than in the female. The legs I are usually of a deep salmon color (this not being the case with the female). Body cuneate-ovate, widest at the anterior region of the abdomen, the cephalothorax rounded in front, abdomen tapering to an acute point posteriorly; bristles arranged very similarly to those of the female, but of considerably greater length and prominence, the frontal pair not over half as long as the subfrontal pair, which, like the median pair next behind, are in length equal to two-thirds the greatest width of the body. Relatively the legs are longer in the male than in the female. Tip of upper side of third joint of palpi with a short, stout, curved spine. The penis (Ewing, 1913) is short, stout, and has a hook at its end which turns upward and ends in a flattened barb. A measured series of males yielded the following dimensions: Length (anterior margin of cephalothorax to tip of abdomen), 0.256 mm.; width, 0.142 mm.; foreleg, 0.256 mm.

Color variations.—The color variations of the male are very slight compared with those of the female. Nearly all individuals conform to one type, which is of an amber-yellow color.

GENERAL FEATURES.

Structural variations.—The microscopic characters of the palpus of the red spider (Pl. III, figs. 1 to 7) are rather variable. The relative dimensions of the terminal "finger" show considerable diversity. The number of bristles between the terminal "finger" and the sub-basal "finger" varies at least from 1 to 3; also, the size and outline of the sub-basal "finger" is subject to some variation. (Pl. III, figs. 13, 14.) Similarly, the character of the tarsal appendages (Pl. III, figs. 8 to 12) exhibits some modifications.

Proportion of sexes.—Worsham (1910) states that in Georgia less than one-fourth of the fertilized eggs produced males. In a large number of rearing tests conducted at Batesburg the total male and female progeny from fertilized eggs was found to be 39.7 per cent and 60.3 per cent, respectively. The ratio of four males to six females represents fairly well the usual proportion of the sexes. When development is normal, the ratio of females to males (based on the foregoing computation of sex ratio) will remain about six to four. At the time of the active migratory movements of females, with their resulting isolation without male individuals, reproduction takes place parthenogenetically for awhile. Since unfertilized eggs invariably bring forth male individuals, the progeny of these isolated unfertilized migrants will be males, and following such migrations a superabundance of males is frequently observed; also, the ability of males to evade capture by predatory enemies or to withstand the action of wind and rain may account partly for the increased number of males which occurs at times. In the fall there is a tendency for the males to predominate which insures the fertilization of the females during the winter.

Copulation.—Several writers have described the act of copulation of the red spider. Perkins (1897) states that the sexes pair at once after the last molt and that one female may receive several males if they are at hand, but that impregnation occurs but once. Von Hanstein (1902), writing of a European form, records many details which agree with those exhibited by the American form. Males are often observed waiting on quiescent deutonymphs, which they excitedly stroke and overrun, as though trying to assist in the molting process. A typical case of copulation may be described as follows: The female, issuing from her deutonymphal skin is immediately attended by one or more males. The female remains comparatively quiet and the male crawls directly under her from behind. The legs I of the male are reached up around the hind portion of the female's abdomen, and the tip of the male's abdomen is then bent sharply upward and slightly forward (fig. 4) until the genital aperture of the male comes in contact with the vulva, which is subterminal. At the approach of a second male the engaged individual usually "backs out" from under the female and upon the departure of the intruding male resumes his former position.

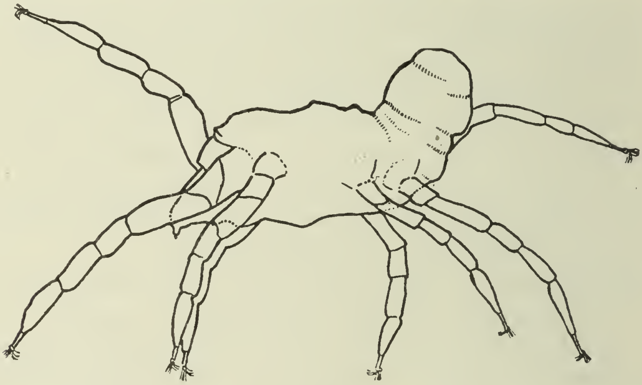

FIG. 4.—Outline sketch of male red spider, showing the characteristic copulatory attitude with reflexed abdomen. (Drawn with camera lucida. 175.) (Original.)

Parthenogenesis.—Perkins recorded that females readily deposit eggs upon failure to mate and that from these unfertilized eggs only males develop. He also states that, after producing a number of eggs, if impregnated subsequently, such females produce a majority of female eggs. Banks (1900) says that the first eggs laid by unfertilized females "produce only males, which, when adult, will pair with the females, and the latter will then lay eggs producing both sexes." Morgan determined that eggs from unfertilized females were viable and capable of development. Ewing reared to adult 52 eggs of three virgin females and all of them became male.

While it has been known that unfertilized eggs become male individuals, no effort has been made, apparently, to test the potency of agamic males. Upon a few occasions parthenogenetic males have been isolated with virgin females, which deposited the usual number of eggs and developed individuals of both sexes in the usual proportion. Since ordinarily these virgin females would have deposited eggs producing males, it is demonstrated by the equal representation of female progeny in such matings that the parthenogenetic male is completely potent.

Parthenogenesis has a very important rôle in the biology of the common red spider. Earlier writers have shown that it works to maintain a relative equilibrium between the individuals of the sexes. Migrating females very frequently establish themselves without having been fertilized, and they are very likely to be without males subsequently. Thus in the event that they arrive unfertilized, their offspring will all be male, and upon the maturing of these male broods the "pioneer" females will at once begin laying fertilized eggs, which will maintain the sexes nearly even.

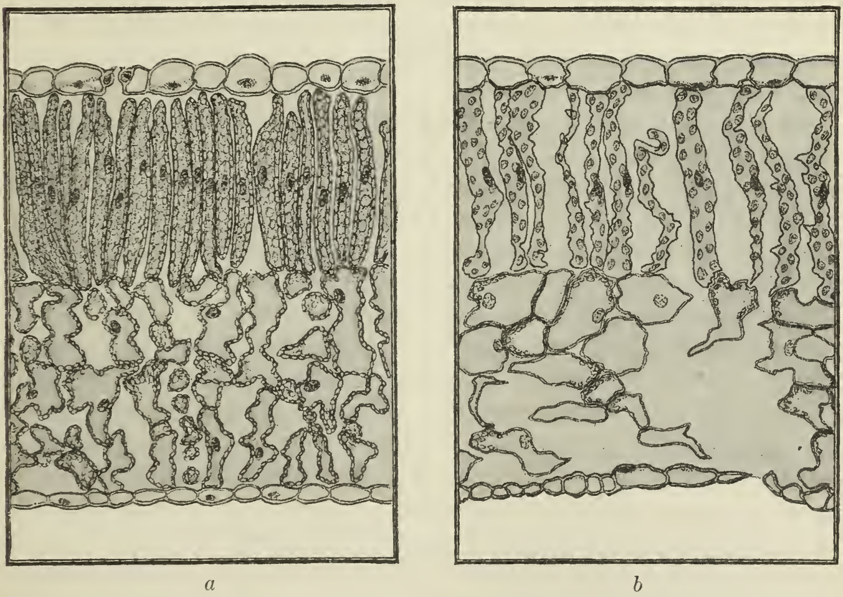

FIG. 5.—*a*, Cross section of normal cotton leaf; *b*, cross section of cotton leaf injured by the red spider. The puncture is near lower right-hand corner. Highly magnified. (McGregor.)

Feeding and injury to plants.—All stages of the red spider, as before stated, feed actively upon the leaf of the host plant. The feeding operation is accomplished by means of sharp, slender, lance-like mouth parts which are thrust through the epidermis well into the leaf, usually on the underside. In the case of cotton, which is typical, the puncture is made through the underside. The consequent siphoning out of the cellular material in the immediate vicinity of the puncture results in the impoverishment of the immediately adjacent tissue (see fig. 5). The parenchymal cells are ruptured and the palisade cells become shrunken and distorted. Each incision of the stylets causes a blackish spot, and after much feeding the infested leaf becomes thickly spotted underneath. There is a change of color in the portions of the leaf attacked which develops especially on the surface immediately over the injured area. In the early stages of infestation this coloring reveals itself as small blood-red blotches, which vary with the number of mites present and with the extent of surface attacked. As leaves become more heavily infested the entire leaf often becomes involved and the effect is soon very marked. The petiole droops to a marked extent, and the entire leaf turns rusty red and later becomes brown and dry. The lower leaves are first attacked, but infestation spreads upward until the plant becomes almost completely defoliated. If the progress of the pest is checked, through natural conditions or by spraying, the health of the foliage is frequently restored and only a few leaves may be shed.

The nature of the injury to plants other than cotton is not materially different from that just described. It is not, however, usual for most plants to exhibit the red blotching. In the case of garden beans, hollyhock, sweet peas, and many other hosts (Pl. IV, figs. 2, 5, and 7) the badly affected leaves assume an ashy hue due to the presence of innumerable grayish puncture specks.

Web spinning.—For more than 100 years the red spider and its close relatives have been known as spinning mites or "spinnemilbe," owing to the ability of these creatures to construct webbing. There is still uncertainty, however, regarding the nature and location of the spinning apparatus, some workers claiming that the glands are located near the mouth, while others contend that the threads issue from the anal end of the body. Ewing (1914) asserts that the silk emerges near the anus and that the four-pronged[1] tarsal claw and the tennent hairs, found on the tarsi, are used in its manipulation.

The fibrils formed by this species are so exceedingly fine that they are almost invisible. Many of them together are visible as a silvery sheen on the much-infested surface (Pl. IV, figs. 1 and 2). The strands are not arranged as a symmetrical web, but merely extend from point to point on the leaf, from leaf to stem, or from one leaf to another. Under normal conditions it appears that the thread is not produced during the ordinary wanderings of the mite, but becomes elaborated at special times, as when the host becomes nonsucculent through drought, when the supporting plant becomes overrun by the pest, or in the presence of numerous enemies. As the leaf curls through the loss of juices the threads become separated from the leaf, so that some mites are under and some on the web. The web is normally confined to the underside of the leaf, but on heavily infested plants it may occur on all parts of the host, the whole apical portion of the plant having a silvery appearance.

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[1] In his description of the tarsus Ewing (1914) describes it as "divided into six prong-like elements."

There has been considerable conjecture concerning the function of the webbing. The surface of the leaf is preferred for oviposition, and it is apparently only when overcrowding has resulted in a confusing maze of fibrils that the females resort to the webbing as a medium upon which to place the eggs. Hundreds of mites in experiments have been observed to molt or to prepare to molt, and without exception they have fixed themselves for the quiescent period directly upon the surface of the leaf.

It has been thought by some writers that the travel of red spiders is facilitated by the presence of the web and that travel upon certain hirsute plants is practically impossible without the aid of webbing. In our work mites have been seen crawling readily over the surfaces of all sorts of pubescent and hirsute plants which possessed no trace of webbing. We have tested larvæ, nymphs, and adults on the pilose surface of velvet and find that they travel readily over the innumerable projections of the pile.

The suggested aerostatic rôle of the webbing in conveying mites through the air seems improbable. We have never seen web appearing as though damaged by wind, and neither in the experiment by Mr. E. E. Munger during 1912 in California on wind dispersion nor in those of a similar nature conducted at Batesburg has a trace of web been detected on the screens coated with a sticky substance, although many red spiders have been thus taken.

We believe that the function of the webbing is that of protection. Among the agencies against which this protection undoubtedly serves are: Spattering raindrops; upward bombardment of soil particles during heavy storms; jarring of foliage caused by driving storms, wind, or sudden contact; flooding, in the case of prostrate plants; the attack of predatory insects, etc. We have often examined infested leaves the undersides of which were heavily coated with soil particles, and after carefully removing the web found the mites uninjured and active behind the protective canopy. On other occasions following heavy downpours leaves not supplied with webbing have frequently been observed completely freed of the red spider, whereas leaves bearing webbing, although subjected to the same storms, still retained a great many mites. Again, low, prostrate plants have frequently been examined following flooding rains and the lowest leaves often found to be heavily coated beneath with a deposition of scum that had been left upon the retreat of the surface water. In such cases, when web had intervened between the mites and the water, the creatures survived the flooding and could be found pursuing their various activities without serious impediment.

In the course of many field examinations we have often seen predatory insects which had been entangled in the red spider's webbing and had perished. *Triphleps insidiosus* and other species have been frequently caught in this manner. As Quayle (1912) has recorded; Arthrocnodax appears very much at home among the fibrils of the mite web and probably derives some protection from the chalcidid Aphanogmus.

Clustering before rain.—Immediately before heavy rains mites are often seen clustered in groups. This was never seen at any other time than just prior to the first drops of a heavy rain.

NATURE AND EXTENT OF DAMAGE TO COTTON IN THE SOUTH.

The detailed account of the specific feeding method and immediate injury inflicted by the red spider we have already presented. It has been shown that severe infestation causes such a lessened vitality, and possibly toxic condition, that a shedding of the leaves and bolls is induced. In severe cases the death of the stalk usually follows the complete defoliation of the plant. However, the loss of foliage (Pl. V, figs. 1–3) is always accompanied by the shedding of the bolls, which may amount to the total elimination of the fruit or to the loss merely of the younger bolls. In the case of stalks which have suffered the complete loss of foliage but which have retained certain of the oldest bolls, the latter may open and produce lint, if sufficiently mature. These defoliated plants are rarely productive of any considerable amount of cotton, though in some cases they develop considerable adventitious foliage and may become restored almost to normal appearance.

The damage worked by red spiders in cotton fields varies in intensity and extent according to the nature of the dispersion centers, and depends on whether control measures have been applied and upon other factors. In 97 cases brought to our attention during one season (1912) the average infested area for each case was 21 acres. In other words, a total of about 2,037 infested acres of cotton was voluntarily reported from South Carolina during one season. It is a conservative estimate to presume that this does not represent over 10 per cent of the total affected acreage in the State for that year. This would make the infested area in South Carolina about 20,370 acres, which would normally produce a crop of about 13,580 bales or 6, 790,000 pounds. The proportionate part of this output that might be expected to be lost through the ravages of the red spider is about two-fifths, or 2,716,000 pounds. At 12 cents per pound for the staple, this lost lint will represent a tax of $325,920 to the State, and the value of seed correspondingly lost would ordinarily amount to $67,900. Our figures thus indicate that during the season of 1912 the red spider caused a loss of about $393,820 to the cotton planters of the State of South

Carolina. Considering the fact that North Carolina, Georgia, Alabama, and Mississippi are known to suffer from the pest practically to the same degree as does South Carolina, it is within all probability that the Southeast, during a severe red-spider year, may suffer a loss of $2,000,000 from the ravages of this pest. As discussed under another heading, the occurrence of the pest during certain years is comparatively light, and the resulting injury is correspondingly reduced.

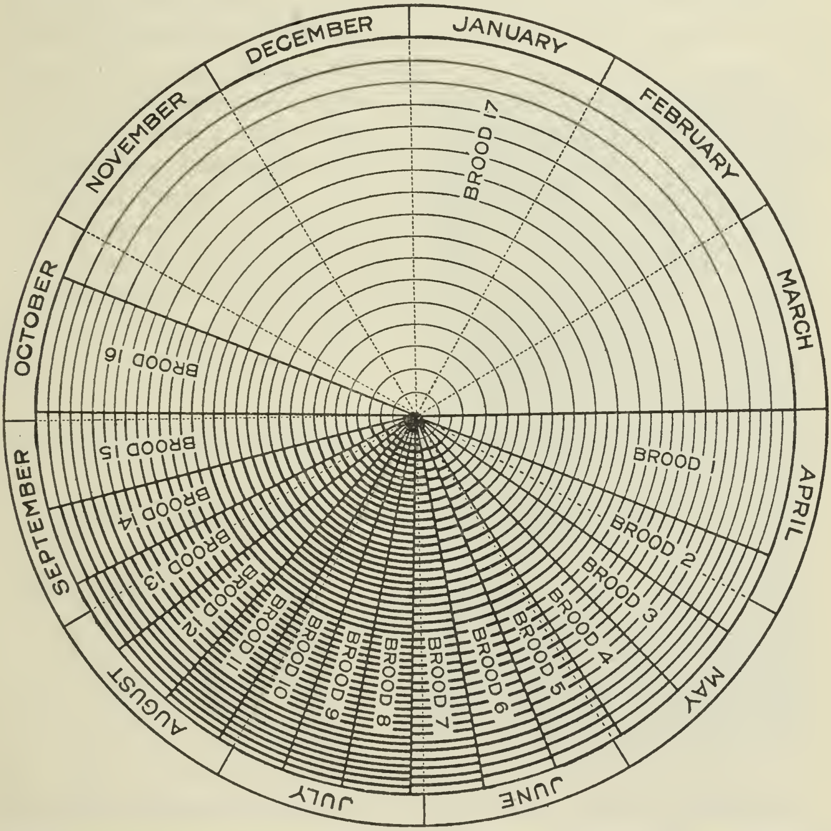

FIG. 6.—Diagram illustrating the sequence of the usual 17 generations of the red spider in the course of one year. (Original.)

GENERATIONS OF THE RED SPIDER.

Regarding the number of generations at any given locality very little has been published. Ewing (1914) states that in Oregon the activities usually begin early in May and that hibernation commences in October. This furnishes an active season of about 180 days, which, divided by 19.7 days (the duration of the life cycle based on his averages), gives nine generations occurring at Corvallis for the season. Worsham (1910) states that in Georgia there are 10 successive generations in seven months, each requiring about three weeks for completion.

At Batesburg the average time required throughout the active season for the completion of a generation is 10.7 days. Since there are normally about 180 active days per season at that locality, it follows that there should be approximately 17 successive broods in South Carolina. This estimate is borne out further by the actual observations in the field.

In 1911 the wintering brood (eggs of the preceding fall and winter) reached maturity about March 11; the 1911–12 wintering individuals matured about April 17; March 25 marked the arrival of the 1913 initial brood of adults; and in 1914 the wintering generation again completed its development about March 25. The average date of appearance of the first spring brood at Batesburg is computed from the foregoing records to be March 31. The time required for a single generation varied from 170 days during the winter of 1911–12, and 35 days in March and early April, to 10 days throughout the summer. The generations, as indicated in Table III and figure 6, are the composite averages of all our continuous records of the past four years and undoubtedly represent the normal sequence of broods in South Carolina.

Table III.—*Seasonal sequence of the 17 annual red-spider broods at Batesburg, S. C.*

Brood.	Commencement.	Completion.	Duration.	Brood.	Commencement.	Completion.	Duration.
			Days.				*Days.*
1......	Mar. 31	Apr. 22	22	11.......	Aug. 3	Aug. 12	10.7
2......	Apr. 23	May 5	13	12.......	Aug. 13	Aug. 23	10.7
3......	May 6	May 17	12	13.......	Aug. 24	Sept. 3	11
4......	May 18	May 29	12	14.......	Sept. 4	Sept. 15	13
5......	May 30	June 9	11	15.......	Sept. 16	Sept. 30	15
6......	June 10	June 20	10.7	16.......	Oct. 1	Oct. 22	22
7......	June 21	July 1	10.7	17.......	Oct. 23	Mar. 30	159
8......	July 2	July 11	10.7				
9......	July 12	July 22	10.7		Total..	....	365
10......	July 23	Aug. 2	10.7				

In sheltered locations winter development may continue sufficiently long to result in the maturing of one or more extra generations. While instances of this are comparatively rare, they are of considerable biologic and economic importance.

Rearing experiments.—Practically all of our experimental data covering life history and biological statistics were secured through the use of a special type of rearing cell which is attached directly to the leaf of the living plant (fig. 7).

The individuals to be reared or experimented with are carefully introduced into these cells by means of the finest camel's-hair brushes. The felt confining pad permits the free passage of air, so that the conditions within the cell are nearly normal. It was found that in rearing cells attached close to the ground quicker development resulted than in those attached higher on the plant. As this arises through heat reflection from the soil, the rearing cells were attached usually at points 3 or 4 feet from the ground in order to eliminate this surface radiation in so far as possible.

SEASONAL HISTORY.

Over-wintering habits.—Several European writers have stated that the common red spider of the Continent passes the winter in a state of hibernation under bark scales or in the ground. Dugès found this species under stones and concluded that they reached the ground with the falling leaves. Von Hanstein (1902) found them during the winter in large numbers in the ground near trees which had been severely infested. He states that mites are often so thick about the crown of the tree roots that when the soil is removed they become plainly visible from some little distance, and adds that the red spiders fashion wintering quarters in the protective crevices of the bark. In Colorado, Weldon (1909) determined that the winter is spent in the ground, and states that myriads of red spiders were found below the soil surface at the crowns of trees upon which they had been feeding. Some were found at a distance of 10 feet from the trees, where they had crawled beneath clods of soil to hibernate. Weldon states that hibernation begins before the cold weather sets in, the first downward migration of mites occurring toward the end of July. Wilson (1911) (Batesburg, 1910) entertained the belief that the red spiders overwinter on cotton plants near the base of the stalk, and was certain that they hibernate about the roots of cultivated violets. Worsham (1910) seems to have been the earliest investigator to recognize the fact that in the Southeast, at least, the red spider passes the winter actively in the adult stage, and even propagates sparingly at temperatures slightly above freezing. He found small colonies housed during the winter on

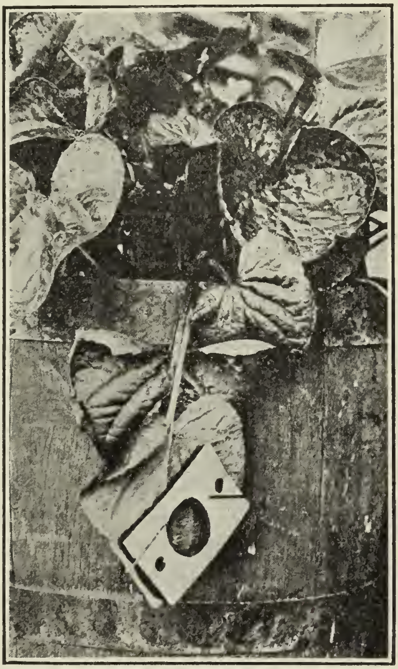

FIG. 7.—Type of isolation cell employed for the life-history and other developmental studies of the red spider. Attached to violet leaf. (Original.)

several species of plants then bearing green leaves. Ewing (1914) states that in Oregon the females enter the period of hibernation in October, and that males are not found during winter.

At Batesburg we have repeatedly investigated hibernation. Old cotton stalks, trash from in and around recently infested cotton fields, dormant weed stalks, violet roots and crowns, and similar material (gathered from localities of recent infestation) were collected during winter and placed in a large Berlese apparatus. The results were always negative. Many examinations have been made of dormant cotton stalks and other plants which had, during the previous season, harbored mites. We have never recovered living red spiders from these dormant hosts. In short, there is absolutely no evidence which would lead to the belief that hibernation occurs in South Carolina. The pest maintains itself throughout the winter on several species of wild and dooryard plants. We have traced infestation through four successive years, from the primary sources to cotton fields and back to the wintering hosts, and have established the botanical sequence which constitutes the successive migratory steps of seasonal activities.

The dispersion of the pest is determined largely by the nature and location of the plants upon which the mites overwinter. These hosts are divisible into summer hosts and winter hosts. Under summer hosts we place such species as harbor mites through the summer and which remain green throughout the winter, thus furnishing continuous feeding during all months of the year. Hosts of this kind are of vast importance in that they obviate the necessity of fall migration on the part of the mites. Among the more important plants of this type are the cultivated violet, strawberry, hollyhock, mustard, privet, and grass (*Panicum scoparium*). It is probably true that comparatively few infestations in cotton arise directly from these summer hosts. The balance of the mites persist through winter on the winter hosts. These include the native weed species which germinate or put out basal leaves in the fall, and to which a certain percentage of the migrants, from cotton and other annual plants, disperse. Whereever these weeds are allowed to grow in great profusion they are usually found to be infested, and when occupying positions close to cotton fields they constitute centers of direct invasion. Among the more common of the winter hosts in South Carolina are *Stachys arvensis*, *Geranium carolinianum*, *Rubus* sp. (wild blackberry), *Chenopodium botrys*, *Sonchus asper*, and *Oenothera laciniata*. Since the great mass of red spiders pass the winter on the wild plants, it is evident that these plants are of great importance. They occur commonly in dense borders along ditch banks, in field borders adjoining areas planted to cotton, in dooryards, and bordering roadsides.

Practically all of the winter hosts possess only prostrate leaves during the late fall and winter. This makes the foliage more accessible to the mites which may be crawling about in search of green plants, and, likewise, the basal leaves favor greatly the reestablishment of red spiders which may become stranded while being carried in surface water.

Appearance of spring adults.—The date which marks the maturity of the progeny of the females which wintered through from the preceding fall is subject to some variation. In 1911 the first spring brood was maturing as early as March 11, while in 1912 the first females did not appear until about April 17. In both 1913 and 1914 this brood matured about March 25.

Time of violet devastation.—Usually toward the end of May the cultivated violet plants in the Southeast become so completely overrun with red spiders that they are killed to the ground. The first indication of damage to violets is the presence of russet spots on the leaves. As the infestation increases the appearance of violet borders is as though they had been fire swept. Those who see them invariably believe they have been killed by drought. (Pl. IV, fig. 4.) When violets grow within a few hundred feet of cotton they may constitute the immediate source of infestation.

The average date of maximum injury to cultivated violets, as shown by the observations of the last four years, is found to be May 25. This is important in the seasonal history of the red spider, since the death of so many violet plants precipitates the migration of the mites, with the result that the pest becomes established on many new hosts.

Time of establishment on cotton.—The earliest date for the establishment of the red spider on cotton varies somewhat from season to season. The time depends largely on the date of appearance of the crops, since we frequently find females established on seedlings which are only three or four days old. Mites have occasionally been seen established on cotton as early as the 1st of May, but for the seasons 1911, 1912, 1913, and 1914 the average for the first records on cotton is computed to be May 20. The lower (sandy) section of South Carolina averages one-half month earlier in the pest's appearance than does the upper (clay) section, June 25 marking the time of the beginning of damage for the former and July 10 for the latter.

Time of severest infestation.—The progress of infestation in a given field depends on several interrelated factors, such as temperature, precipitation, natural enemies, etc. Furthermore, there are successive waves of infestation occasioned by the favorable and the inimical natural agencies. In 1911, at Batesburg, a cotton field was seen very acutely infested on June 12, while in 1913 fields were seen badly infested as late as September 6. Most of the severe infestation, however, occurs during July and August. By averaging the dates of occurrence of a considerable number of acute cases in our files we obtain July 26 as the date of heaviest infestation.

Approximate date of reduction in numbers.—During each of the four years of the red-spider investigation there has occurred at some time of the season a sudden reduction in the numbers of the pest due to the abundance of natural enemies. Unfortunately, this is not general and simultaneous throughout the South. Furthermore, the mite reduction occurs at different times from season to season. In 1911 it did not take place in central South Carolina until about the 1st of September, whereas in 1912 the pest was controlled as early as July 10. In 1913, July 20 marked the approximate date of decimation, and in 1914 the phenomenon occurred about July 20. For the four seasons, the average date of the reduction of the red spider by its insect enemies is found to be about July 15.

Following these seasonal decimations the mites are often reduced almost to extinction, which naturally reacts against the predatory species in due time, and in their absence a secondary impetus is usually noted in the development of the red spider. These secondary occurrences seldom result in serious infestations, but have the result of restoring somewhat the status of previous cases. This numerical revival may be looked for usually between the middle and last of August in South Carolina. (See fig. 8 for seasonal status curve.)

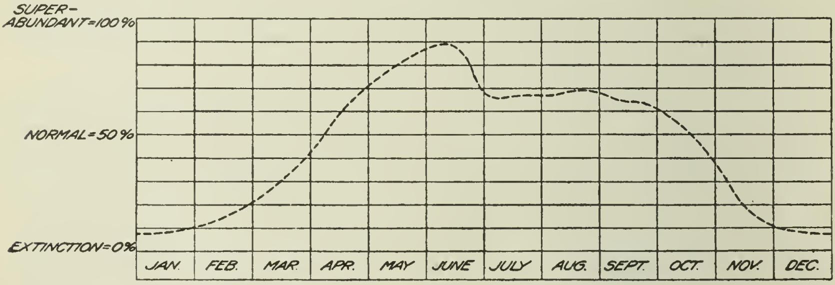

FIG. 8.—Curve representing the 4-year composite seasonal status of the red spider in central South Carolina. The depression of the line in June represents the decimation arising through the activity of predatory enemies. (Original.)

Fall and early winter status.—In parts of the world where the red spider hibernates the mites prepare to leave their host plants at the approach of winter and seek shelter in the ground or under the bark scales at the base of the trunk or stem of trees. In South Carolina, the mature mites assume the characteristic orange-yellow color with the arrival of late fall.

The mites which live through the winter are to be found usually on the basal leaves of a few dooryard plants, such as English violet, hollyhock, strawberry, and mustard, and upon several native species of weeds, etc., which offer green leaves. Every stage, from egg to adult, of both sexes has been repeatedly encountered during winter. The immature individuals produced in brief intervals of favorable weather are almost certain to perish with the return of lower temperatures.

Variation in abundance from year to year.—It is noticeable that the degree of occurrence varies greatly from year to year. We find from a study of the various natural influences that it is possible to foretell the probable status of the pest during a given season with considerable assurance. The red spider is extremely resistant to adverse meteorological conditions, and no matter how severe the winter, a considerable proportion of the mites come through safely. On the other hand, many of the insect species which are predatory upon the red spiders, being of a more susceptible nature, are less likely to survive the hardships of a severe winter. Theoretically, after a mild winter there should be an abundance both of mites and predators, while after a severe winter the mites should survive in a much greater proportion than their enemies. This condition has obtained during the past four years, mild winters being followed by mild red-spider seasons, while severe winters have been followed by seasons of heavy mite occurrence.

DISPERSION.

When the food supply on favorable host plants becomes exhausted dispersion to new food plants takes place, and it is usually by a succession of such dispersions that cotton finally becomes infested.

Ground travel.—On many occasions red spiders have been observed crawling on the ground in the vicinity of grossly infested plants, frequently crawling up and down the stems in search of more favorable hosts upon which to feed. In order to ascertain whether red spiders leave the plants of their own volition and crawl upon the ground in attempts to extend their range, the following experiment was instituted.

Tests of red-spider movements.—Large sheets of sticky fly paper were carefully fitted about the bases of cotton stalks. The sticky surfaces were permitted to remain in this position for periods varying from 24 to 48 hours. At the conclusion of these exposures careful examinations were made, of which the following specific results are rather typical: Five red spiders were observed on the inner edge, which came in contact with the base of the stalk; 29 mites were caught on the extreme outer edge, which was flush with the finely packed soil; 5 red spiders were found ensnared at dfferent points in the central area of the sticky surface. The only possible deduction is that the first-mentioned 5 individuals were intercepted as they were descending the stem; that the 29 mites were trapped as they were crawling over the ground surface, presumably toward the cotton stalk; and that the last-mentioned 5 undoubtedly dropped directly from the overhanging foliage.

Manner of travel.—An extensive series of experiments concerning the travel of red spiders has been performed. The female travels in a comparatively straight course, being influenced by the light. (Pl. VI.) The female travels faster than the male and her effort is extended over a relatively large space in an apparent attempt to locate new food plants. The very frequent observance of solitary females on seedling plants is positive evidence that they establish themselves through the agency of ground travel.

The male, on being removed from the host plant and tested on a comparatively smooth surface, confines his wanderings to a small area. The tracings made of male travel are seen to cross and recross until a maze of lines results. No evidence of phototropism has been observed in many cases of male travel. There seems to be an instinctive tendency to remain within a limited area. The entire area traversed in an hour by the average male on a smooth surface rarely exceeds in size that of a watch crystal. The aversion to roaming probably originates from the instinctive desire to remain with the females of the colony. It is not essential to the propagation of the species that migrating females, which failed to mate before undertaking their journeys, should become fertilized immediately upon establishing themselves on the new host. As has been emphasized previously, the early eggs of such sterile females produce only males, which, upon maturity, immediately fertilize the females, so that the subsequent progeny will be of either sex.

TABLE IV.—*Distance and rate of travel of male and female red spiders on coarse paper surface.*[1]

Exp. No.	Male.				Female.									
	Warm Day.				Warm day.					Cool day.				
	Time.	Distance.		Rate per minute.	Exp. No.	Time.	Distance.		Rate per minute.	Exp. No.	Time.	Distance.		Rate per minute.
	Mins.	*Ft.*	*In.*	*Inches.*		*Mins.*	*Ft.*	*In.*	*Inches.*		*Mins.*	*Ft.*	*In.*	*Inches.*
1	30	4	2½	1.68	15	31	10	11	4.25	27	60	9	0	1.80
2	30	5	9	2.30	16	26	10	7	4.85	28	60	8	10½	1.77
3	30	5	6	2.20	17	60	18	9	3.75	29	60	6	1¾	1.23
4	30	5	2	2.06	18	60	26	0	5.20	30	60	6	3	1.25
5	12	2	1	2.08	19	30	13	9	5.50	31	30	4	½	1.60
6	8	2	0	3.00	20	60	20	9½	4.16	32	30	3	10½	1.55
7	15	5	7	4.47	21	30	13	1½	5.25	33	45	9	1¼	2.43
8	15	4	5	3.53	22	30	8	10½	3.55					
9	40	12	7	3.78	23	21	11	11	6.80					
10	16	3	7¾	2.73	24	31	10	10	4.20					
11	15	5	4½	4.30	25	26	10	7	4.90					
12	15	4	8	3.73	26	30	13	8	5.47					
13	45	9	3¾	2.48										
14	30	7	3	2.90										
Av.				2.95					4.82					1.66

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[1] The mean temperature at the time of conducting the warm-day experiments was 91.2° F., and at the time of conducting the cool-day experiments was 62.7° F.

Rate of travel.—In order to ascertain the rate of movement of wandering red spiders a series of laboratory experiments was conducted. A large sheet of coarse wrapping paper was fastened tightly on a 4 by 6 table. The red spiders to be tested were liberated at the center and their progress was traced for periods varying from 5 to 90 minutes.

The influence of temperature on the rate of travel was very marked, and was established by conducting the foregoing tests on both hot and cool days. It also develops that the average rate of travel by the female red spider in summer is 4.82 inches per minute, while that of the male under similar conditions is 2.95 inches per minute. (See Table IV.)

SOURCES OF DISPERSION.

When cotton fields occur in urban localities it often happens that infestations arise directly from garden or dooryard plants, such as the violet, sweet pea, dahlia, hollyhock, garden bean, etc. (Pl. IV, figs. 3–5; Pl. V, fig. 4.) As has been pointed out, however, the pest more usually reaches cotton in the course of a series of migrations, beginning with the primary hosts as foci, and advancing from host to host as the native species appear above the ground in spring. The plants which so happen to harbor the pest in situations adjacent to cotton, when the latter appears, become the immediate sources of dispersion to the cotton field.

Weed borders (Pl. V, fig. 5), which have been known to give rise to very acute infestations in adjoining cotton fields, and which prevail throughout the entire year, have been made the subject of continued observation, with the result that the position of such weeds in the problem is now quite clearly understood. There are certain weed species that at times occur in almost pure growths; that is, countless thousands of seedlings of a given species may grow in continuous, dense borders. This was often noticed at Batesburg, where at times weed infestation became so acute that entire borders of *Geranium carolinianum*, *Stachys arvensis*, etc., wilted, and finally succumbed entirely. It is just such cases as these that produce a migration of red spiders to the cotton fields. A rather complete list of the native plants at Batesburg which are of great importance in advancing the red spider to cotton in the spring is given in Table V.

TABLE V.—*List of important spring weed hosts of the red spider, Batesburg, S. C.*

Stachys arvensis.
Chenopodium botrys.
Sida rhombifolia.
Geranium carolinianum.
Trifolium repens.
Sonchus asper.
Vicia sativa.
Taraxacum officinale.
Gnaphalium spathulatum.
Rumex obtusifolius.
Oenothera laciniata.
Oxalis stricta.
Panicum scoparium.
Helianthus annuus.
Convolvulus sp.
Plantago lanceolata.
Croton texensis.
Rumex crispus.
Stellaria sp.
Solanum carolinense.
Solanum nigrum.
Ipomoea purpurea.
Passiflora incarnata.
Lechea villosa.
Brassica campestris.
Wild grass.
Rubus sp.
Phytolacca americana.
Ambrosia artemisiaefolia.
Amaranthus hybridus.
Datura stramonium.
Erigeron sp.
Xanthium americanum.

WATER DISPERSAL.

For a long time investigators of the red spider found it difficult to explain why isolated infestations existed in fields comparatively remote from the source of dispersion. It has been known for years that heavy rains dislodge many red spiders, and it has been taken for granted that these mites were destroyed. We have established the fact, however, that 9 hours' submergence in water is necessary to cause the death of red spiders. Beaten to the ground by the heavy downpour of rains, countless thousands of mites are carried along in the surface water and may even find their way into the smaller creeks. Provided the red spiders are not injured, they may revive and become established many rods, perhaps, from the scene of detachment. Table VI presents the data on submergence of mites and the resulting mortality.

TABLE VI.—*Submergence and red spider mortality, Batesburg, S. C., 1914.*

Experiment No.	Exposure.	Interval before examination.	Mortality.	Condition of individuals not recovering.	Experiment No.	Exposure.	Interval before examination.	Mortality.	Condition of individuals not recovering.
	Hours.	*Hours.*	*Per cent.*			*Hours.*	*Hours.*	*Per cent.*	
1	24	12	100	Macerated.	11	12	4	100	Shrunken.
2	24	12	100	Do.	12	9	3	100	Do.
3	24	3	100	Shrunken.	13	10	6	100	Macerated.
4	24	3	100	Do.	14	11.5	6	100	Do.
5	12	2	100	Do.	15	5	10	50	Do.
6	7	15	[1] 70	Macerated.	16	8.25	4	83	Shrunken.
7	2.5	4	0		17	10.25	6	[1] 95.3	Macerated.
8	17.5	5	100	Shrunken.	18	9	4	100	Shrunken.
9	8	6	50	Shriveled.	19	7	8	95	Macerated.
10	10	6	100	Shrunken.					

[1] A minute air bubble, about which were some of the mites, remained in the vial.

From Table VI it is seen that the shortest period of submergence that will suffice to kill all red spiders is 9 hours. All individuals survived a submergence of 2½ hours, and 50 per cent revived after an exposure of 8 hours.

Observance of water dispersal in the field.—The actual dispersion of red spiders by surface water has been observed repeatedly in the field. In Plate VII a typical case of this sort in a cotton field is illustrated. The primary source of dispersion consisted of cultivated violets growing in a dooryard, indicated by *A*. Upon becoming overcrowded a migration took place from these plants which brought many of them across the street (*B*) and into the cotton field (so indicated), where they became concentrated at (*C*), the point nearest to the violets. This infestation, limited to one end of the field, is indicated by ringed stalks. The heavy rains dislodged great numbers of red spiders and carried them along in the little streams which ran between the cotton rows. This surface water converging at the lowest point of the field, a large percentage of the stranded mites revived and reestablished themselves upon the cotton plants immediately at hand. Thus, at *D* there began a secondary development which tended to spread throughout the field. Naturally this dispersal is repeated with each heavy storm, with the result that these concentrations at the lower points of the fields become more and more severe.

Not all of the mites which are conveyed by the surface streamlets reach the ground through the effect of rains, as many are dislodged by falling leaves, through the weakening effect of heavy infestation, or by early frosts.

PLANT TO PLANT TRAVEL.

It is commonly the case during times of severe infestation that mites spread directly from one plant to another through the interlacing of branches. Such dispersion is facilitated by the close planting of cotton and, inversely, is discouraged by wide spacing. It is difficult to say whether dispersion is accomplished more by means of ground travel or by leaf to leaf travel.

WIND DISPERSAL.

Several investigators have suspected that red spiders may be conveyed considerable distances by heavy winds, but it remained for Mr. E. E. Munger, of California, to conduct serious tests during 1913. He employed sticky fly paper at different heights above the ground and at varying distances from the source, which happened to be a badly infested almond orchard. Mr. Munger found quantities of mites on the sticky surface placed under the following conditions: Twelve feet from the ground and 100 feet from the orchard, 30 feet from the ground and 250 feet from the orchard, and 50 feet from the ground and 650 feet from the infested orchard. All of these tests were made at times when the usual light summer winds were blowing.

We conducted similar tests at Batesburg and were able to corroborate to some extent the results of Munger. In one test we suspended by a string a board bearing on each side two sheets of sticky fly paper. The trap board was then attached to a wire stretched between poles. A sticky substance was smeared on the suspending string to prevent the mites from reaching the sticky surface by crawling. The suspended board was free to swing in any direction, so that mites being borne by the wind from any direction would be intercepted. An orange tree which harbored *Tetranychus mytilaspidis* stood about 300 feet from the exposed sticky surface, and several other host plants infested with *T. bimaculatus* grew within 20 to 25 feet. After an exposure of 36 hours the sticky paper was examined. Ten adult specimens of *T. mytilaspidis* and several immature individuals of *T. bimaculatus* were caught.

During the periods of drought and food scarcity mites have been seen to seek the highest or terminal points of branches, and this habit of the red spider may be closely associated with dispersion by wind. Naturally, this act would bring them to points where the effect of the wind would be greatest.

OTHER DISPERSION AGENCIES.

Several additional agencies have been suggested by various writers as means of spread of the red spider. The operation of cultivating the crop has long been considered to be instrumental in conveying mites from point to point about cotton fields. Titus (1905) maintained that the members of hoe gangs and cultivators are the most common means of distribution. He claimed that mites cling to any substances that brush against them, and in this manner are rapidly and thoroughly scattered over fields. The effect of distribution along rows and across fields, following the routes taken by farm hands, can, he claims, be traced easily by the resulting infestation along these routes. The present writers are inclined to minimize this accidental type of dissemination. Even when manipulated with the finest camel's-hair brush a certain percentage of individuals are killed.

Allied with this form of dispersion is that of accidental transportation by larger insects. Titus states that mites have been taken from several insects, such as grasshoppers and small Hemiptera, which often visit cotton plants. Such agencies of dispersion as insects, domestic animals, poultry, and wild birds should be considered as being of minor importance.

CLIMATIC CONTROL.

Although climatic influences exert an immediate reducing effect over limited areas from time to time, the hardiness and the widespread occurrence of the species insure the survival of sufficient numbers to reinfest localities that may have been thus partially freed. Owing to the fact that there is such a continuous succession of overlapping broods and that every stage from egg to adult occurs simultaneously, it is obvious that the most extreme weather factors can not be expected completely to eradicate the pest.

Climatic conditions do, however, influence the development of the red spider to a marked extent, and this influence may be either detrimental or beneficial. In the occurrence of the seasonal cycle the status of the red spider invariably undergoes a series of fluctuations. Beginning in January (see fig. 8, p. 26) we find the pest maintaining itself. In February no pronounced gain is ever made, although the development of the species may undergo some slight advance or setback due to weather. During March there is a gradual trend toward an optimum, but the pest usually suffers one or more retarding checks from adverse weather conditions. Through April and May the progress of infestation is usually most rapid, so that by the 1st of June development has nearly reached its maximum. Usually some time in June or early July a sudden decimation occurs which reduces the status to normal or below. This reduction is followed by a reaction, so that some time between the middle of July and the last of August infestation again increases. From that time until October, usually, development is subject to fluctuations varying considerably in extent, but the autumn period is characterized by a rather abrupt diminution until, by the end of November as a rule, the minimum again is reached.

Rainfall.—During times of little rainfall and high temperature reproduction goes on very rapidly; on the other hand, long, heavy rains work havoc. In spite of the fact that the mites inhabit the underside of the leaves, many are washed off by rains and others are destroyed by the upward bombardment of sand particles. In fact, it appears true that a few heavy rains, especially if they continue for some time, reduce, temporarily at least, the degree of infestation. Although a temporary reduction of the pest is occasioned by heavy rains, many of the washed-off adults may be carried considerable distances in the surface water at these times, only to revive upon stranding, and to establish new colonies remote from the scene of their rearing. Thus rain has the effect of greatly decreasing the percentage of infestation, while at the same time considerably extending distribution. In one instance a violet leaf, heavily coated with soil, was examined and there remained, out of a recent large colony, only one female, one primary nymph, and numerous eggs. Of eight females remaining on another leaf seven were dead and one alive following a heavy dashing rain.

The progress of infestation in cotton fields has been closely followed on several occasions. The fluctuations in one of these fields, as indicated by careful counts of infested and uninfested plants in large series, was as follows: May 27, 57.5 per cent; June 10, 75 per cent; June 17, 33.3 per cent; June 25, 77.7 per cent, and June 27, 55.5 per cent. A heavy rain fell on June 16, causing the reduction of 41.7 per cent; another fell June 26, causing the reduction of 22.2 per cent.

Drought.—Long-continued drought works, at least indirectly, to the detriment of the red spider. Perkins believed that the pest developed fastest under hot, dry conditions, but also demonstrated that mites are capable of living quite well under very moist conditions. Titus (1905) states that infestation rarely becomes serious unless accompanied by long-continued dry weather. Worsham (1910) asserts that dry and warm weather is essential for the maximum propagation of the spiders and that only during a prolonged drought do their ravages assume serious proportions. Ewing (1914) writes that it is during July and August that the red-spider injury becomes most serious and that these are the hottest and driest months in western Oregon.

Investigations at Batesburg have further confirmed the rule that the most rapid multiplication of the red spider is coincident with periods of maximum temperatures and minimum precipitation. On the other hand, the great rapidity of mite development reacts on the species to its detriment. This reaction occurs in several forms. First, the superabundance of the pest on hosts occasions the drying of the foliage, so that the tissue becomes unattractive. This causes widespread migratory movements, with the result that myriads of the mites perish because of the intense heat of the soil or failure to discover new hosts. Secondly, the concentrated massing of red spiders at such times is to the benefit of their predatory enemies, with the result that the predators in turn increase at their maximum rate.

INSECT ENEMIES OF THE RED SPIDER.

The investigations conducted at Batesburg have added substantially to a knowledge of the insect enemies of the red spider. Three insects were observed by J. C. Duffey (1891) to feed on red spiders at the St. Louis Botanical Gardens in 1891. These were *Scolothrips sexmaculatus*, a chrysopid larva, and *Scymnus punctum*. The latter was observed to exert great control. Morgan (1897) states that a very small black lady beetle (*Pentilia* sp.) was the only insect enemy of the cotton mite noticed during 1893 in Louisiana. Perkins (1897), in his account of the common red spider, mentions no predatory enemies. Titus (1905) records chrysopid larvæ, a species of Pentilia, and other coccinellids as feeding on mites at several localities in 1905.

Chittenden (1909) observed larvæ of *Scymnus punctum, Cecidomyia coccidarum, Chrysopa rufilabris,* and all stages of *Thrips sexmaculatus* to be predatory on red spiders on the Kentucky coffee tree (*Gymnocladus dioica*) at Washington, D. C., during July and August, 1906. He states that the Scymnus larvæ were the most effective. In Colorado, Weldon (1909) found lacewing-fly larvæ and *Scymnus punctum* to be the principal enemies of the red spider. Worsham (1910) states that the only natural enemy observed during the studies in Georgia was *Stethorus punctum,* which fed, both in the larval and adult forms, on the mites and the eggs. It was Quayle (1913) who first gave us a considerable list of red-spider enemies. He does not, however, differentiate between the predators of *T. mytilaspidis, T. sexmaculatus,* and *T. bimaculatus.* He states that most of the observations were made on the citrus mite. Parker's investigations (1913) in central California during 1911 and 1912 revealed the presence of the following predators, which he states he has seen preying upon red spiders: *Triphleps tristicolor* (nymph and adult), *Scymnus nanus, Scymnus marginicollis, Pentilia* sp., and *Chrysopa californica.* The lacewing-fly larvæ were most active. Finally, Ewing (1914) lists the following species as actively predatory on the red spider in Oregon: the mite *Seius pomi, Triphleps insidiosus,* syrphus-fly larvæ, and *Stethorus punctum.* Other species of mites and insects are mentioned by Ewing either as having been reported elsewhere on the Pacific Coast or as being probable enemies. Ewing estimates Seius to be the most valuable red-spider enemy in Oregon. All told, these enemies of the common red spider make a total of a dozen species which, to date, have been reported as definitely feeding upon *Tetranychus bimaculatus.* Neither Parker nor Ewing appears to believe that substantial control accrues from the activities of the red-spider enemies.

In the case of each of the seasons 1911, 1912, 1913, and 1914, during which the red spider has been under observation at Batesburg, S. C., a sudden decimation of a more or less complete nature has occurred. Figure 8, page 26, presents a diagram which consists of a composite curve representing the average seasonal status of the red spider in South Carolina for 4 years. The low summer point, reached in July, indicates graphically the combined control value of predatory species. The red spider at the present time is known to be the host of 31 species of arthropod enemies. Of these, 5 are mites (Acarina), 3 are thrips (Thysanoptera), 4 are bugs (Hemiptera), 4 are lacewing flies (Neuroptera), 2 are midges (Diptera), 4 are syrphid flies (Diptera), 8 are lady-beetles (Coleoptera), and 1 is a noctuid moth (Lepidoptera). These predators, in turn, are known to be attacked by 75 species of predators and parasites.

Plate VIII is a diagram which, to some degree, graphically indicates the complex relation which the red spider bears to its environment. In a number of instances these predatory species also operate against other small insects, such as aphids, scale insects, mealy bugs, white flies, etc. So far as is known, only two predators are enemies exclusively of the red spider, namely, the two midges. One predatory species, the cotton leafworm (*Alabama argillacea*), is only incidentally an enemy of red spiders, through the fact that myriads of mites are devoured along with the cotton foliage. This defoliation occurs generally over the cotton belt from time to time. Two of the predators, in turn, become enemies of other predators as well as of the mites. The most heavily parasitized of the predators are the chrysopids and the syrphids, the mortality of which becomes rather high at certain times.

ARACHNIDA, ACARINA.

GAMASIDAE.

Seius quadripilis Banks.—This mite was collected by Mr. G. A. Runner at Key West, Fla., on a wild grass infested with the red spider, and also at Orlando, Fla., on infested chinaberry leaves by Mr. W. W. Yothers. Its abundance at these localities suggests that it probably exerts considerable control.

Macrocheles sp.—This mite has been found on pokeweed (*Phytolacca americana*) heavily infested with the red spider at Batesburg. It has been observed actively at work in mite colonies, and is doubtless of economic value.

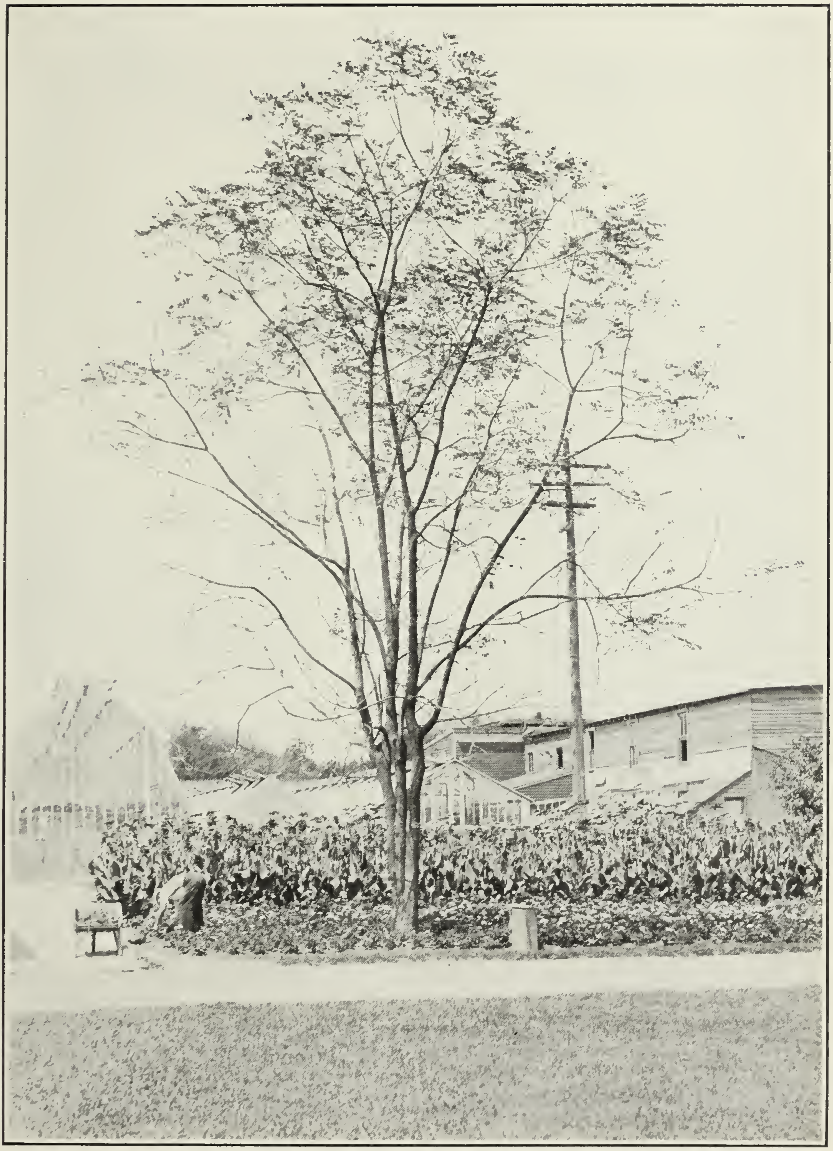
Laelaps macropilis Banks.—Mr. J. D. Mitchell found this mite on two occasions at Victoria, Tex., where it was doing good control work on heavily infested sweet peas. Mr. W. W. Yothers also sent it on badly infested chinaberry leaves from Orlando, Fla., where the species was responsible for the marked decimation of the red spider which occurred in the late summer. This mite is an important enemy of the red spider.

RHYNCHOLOPHIDAE.

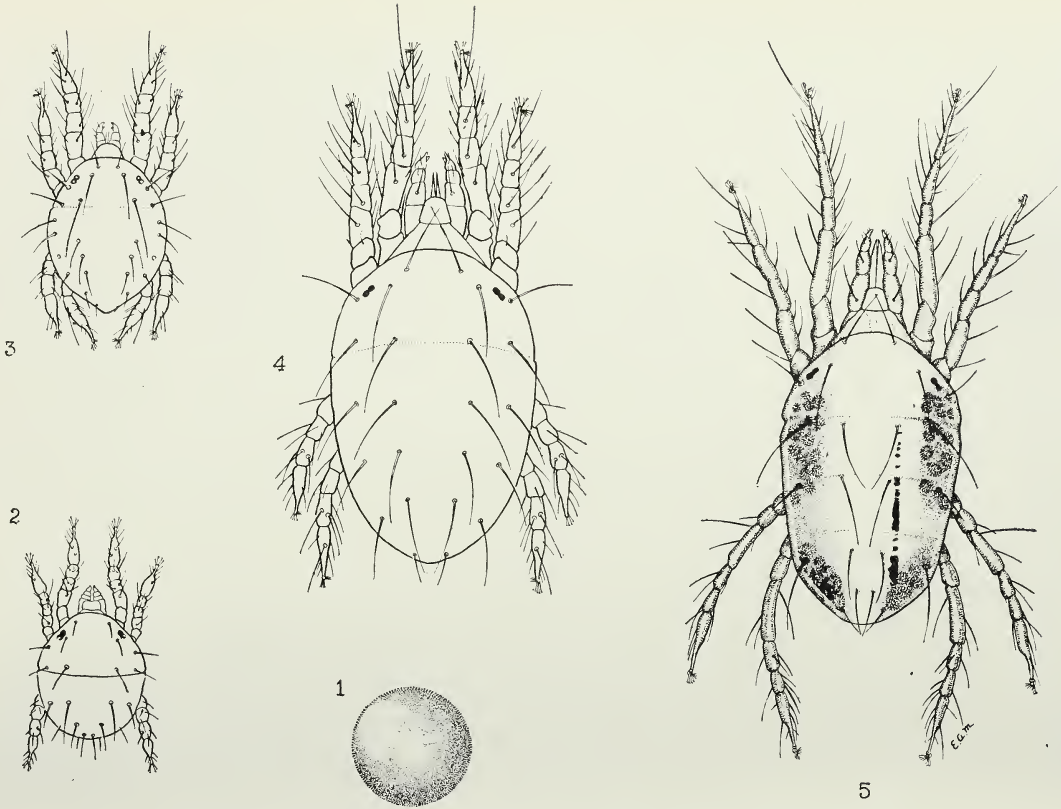
Rhyncholophus pilosus Banks.—This species was observed at Batesburg destroying the red spider on "mare's tail" (*Lechea villosa*) and on Boston ivy.

ANYSTIDAE.

Anystis agilis Banks.—This mite (fig. 9) is frequently seen crawling about in unlikely places in search of food. It is extremely active and follows a tortuous course that sooner or later brings it to its victims. We have collected it from mite-infested elderberry (*Sambucus* sp.) at Batesburg, but have made no accurate estimate of its control value. Ewing reports finding considerable numbers of this mite upon violets, heavily infested with red spiders, in Oregon.



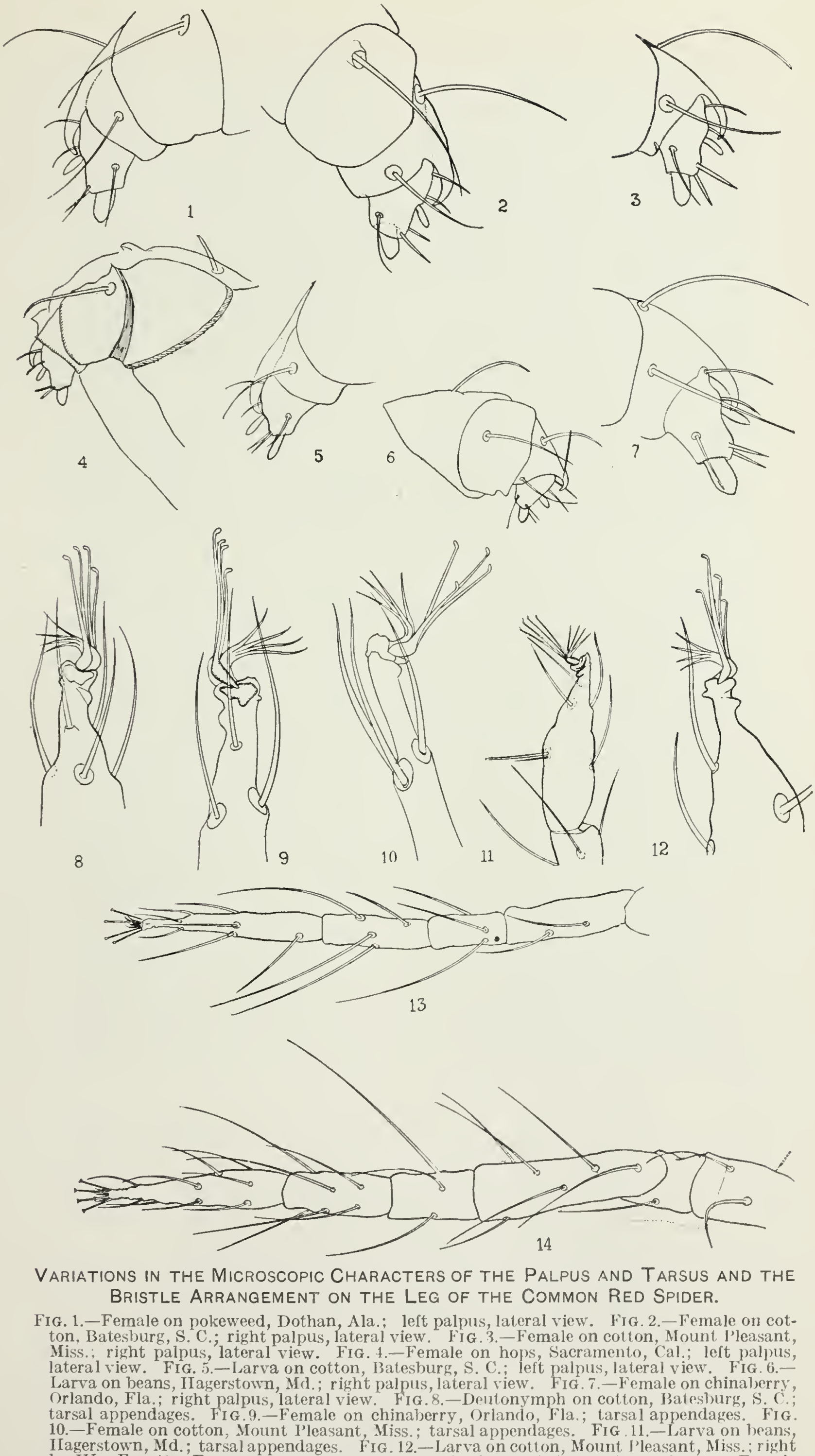
KENTUCKY COFFEE TREE (GYMNOCLADUS CANADENSIS) WHICH HAS LOST MOST OF ITS FOLIAGE THROUGH THE WORK OF THE RED SPIDER (TETRANYCHUS BIMACULATUS). (ORIGINAL.)



DEVELOPMENT OF THE COMMON RED SPIDER (TETRANYCHUS BIMACULATUS).

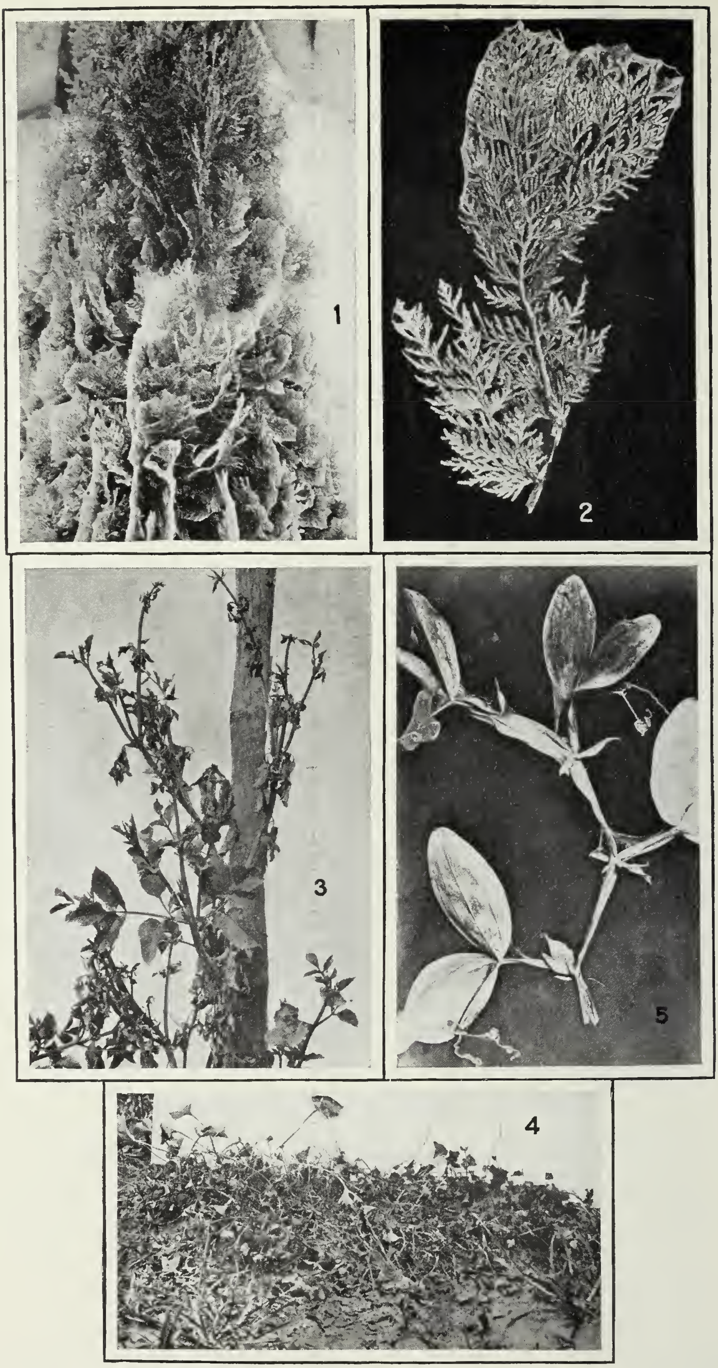
FIG. 1.—The egg. FIG. 2.—The newly hatched larva. FIG. 3.—The recently molted protonymph. FIG. 4.—The mature deutonymph just prior to the final molt. FIG. 5.—The adult female. (Highly magnified.)

PLATE III.



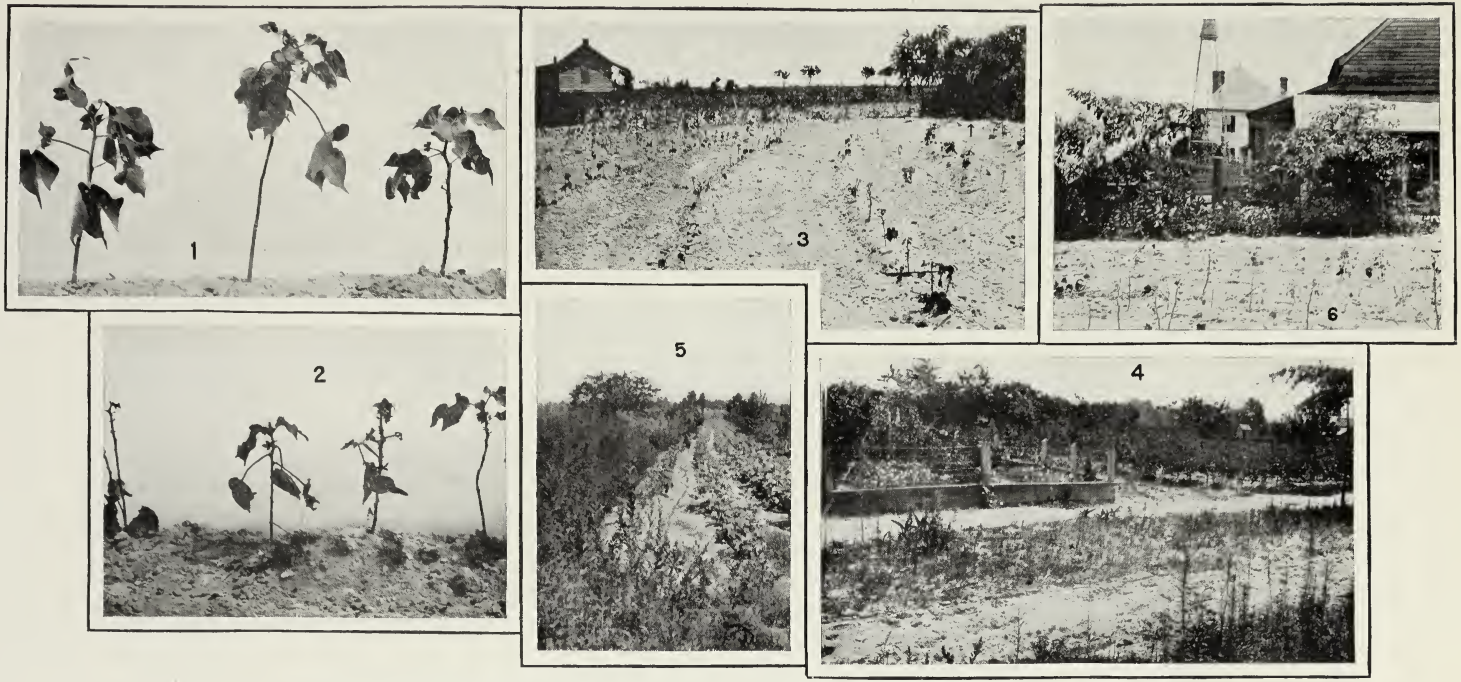
Variations in the Microscopic Characters of the Palpus and Tarsus and the Bristle Arrangement on the Leg of the Common Red Spider.

Fig. 1.—Female on pokeweed, Dothan, Ala.; left palpus, lateral view. Fig. 2.—Female on cotton, Batesburg, S. C.; right palpus, lateral view. Fig. 3.—Female on cotton, Mount Pleasant, Miss.; right palpus, lateral view. Fig. 4.—Female on hops, Sacramento, Cal.; left palpus, lateral view. Fig. 5.—Larva on cotton, Batesburg, S. C.; left palpus, lateral view. Fig. 6.—Larva on beans, Hagerstown, Md.; right palpus, lateral view. Fig. 7.—Female on chinaberry, Orlando, Fla.; right palpus, lateral view. Fig. 8.—Deutonymph on cotton, Batesburg, S. C.; tarsal appendages. Fig. 9.—Female on chinaberry, Orlando, Fla.; tarsal appendages. Fig. 10.—Female on cotton, Mount Pleasant, Miss.; tarsal appendages. Fig. 11.—Larva on beans, Hagerstown, Md.; tarsal appendages. Fig. 12.—Larva on cotton, Mount Pleasant, Miss.; right leg IV. Fig. 13.—Female on cotton, Batesburg, S. C.; left leg I, dorsal view. Fig. 14.—Female on chinaberry, Dothan, Ala.; left leg I, ventral view. All drawn with oil-immersion and camera lucida. Highly magnified. (Original.)



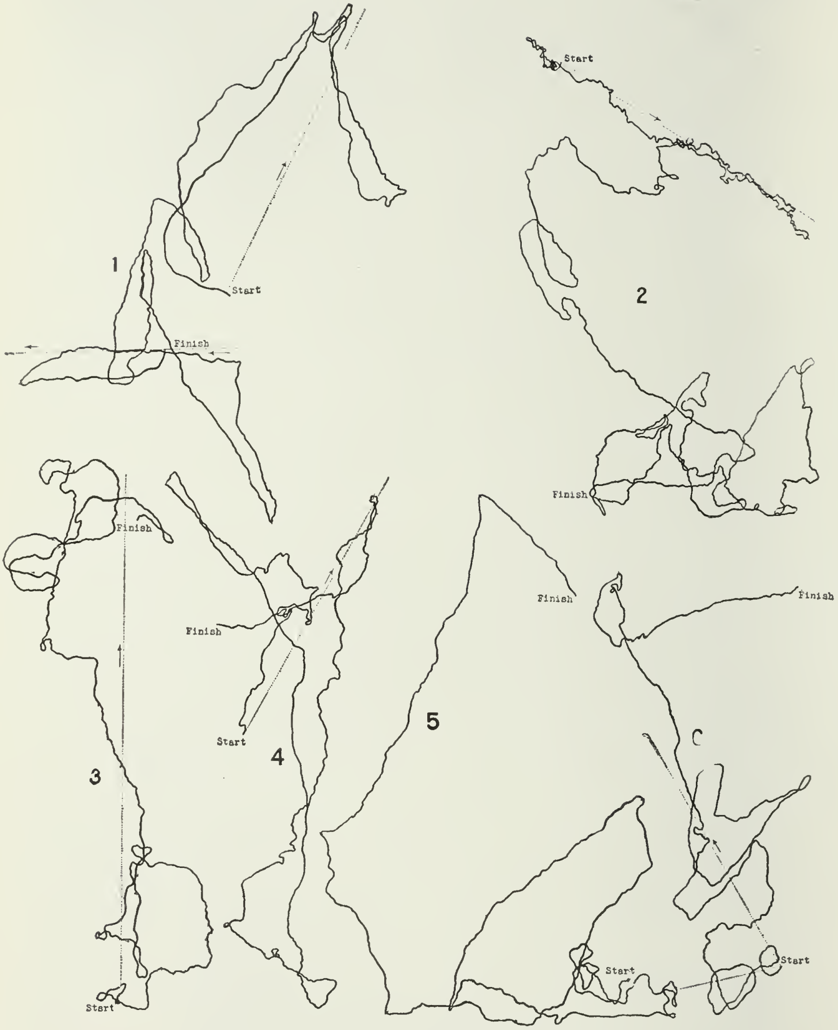
RED-SPIDER INJURY TO VARIOUS HOSTS.

FIG. 1.—Arborvitæ tree heavily coated with mite webbing. FIG. 2.—A branchlet from the tree shown in figure 1, showing enshrouding web. FIG. 3.—Dahlia plant with leaves distorted and shriveled through mite activity. FIG. 4.—Bed of violets dead to the ground from excessive infestation. FIG. 5.—Blanched sweet-pea foliage, also showing webbing. (Original.)



COTTON INFESTATION BY THE RED SPIDER AND SOME IMMEDIATE SOURCES OF DISPERSION.

FIG. 1.—Cotton plants in advanced stage of infestation. FIG. 2.—Cotton plants in the final stages of mite attack. FIG. 3.—Cotton field with plants in the condition shown in figure 2; arrow indicates original source. FIG. 4.—Dooryard flower beds, a serious factor in dissemination when present near cotton fields. (Note cotton growing adjacent.) FIG. 5.—Weed border by the side of cotton field, a common source of infestation. FIG. 6.—Cotton field destroyed by red spiders, and two large pokeweeds from which the infestation arose. (Fig. 3, McGregor; figs. 1, 2, 4, 5, 6, original.)



TRACINGS OF TRAVEL OF FEMALE RED SPIDERS.

FIG. 1.—Mite traveled 143 inches in 21 minutes, or at a rate of 6.8 inches per minute. FIG. 2.—Mite traveled 249.5 inches in 60 minutes, or at a rate of 4.16 inches per minute. FIG. 3.—Mite traveled 111.25 inches in 45 minutes, or at a rate of 2.48 inches per minute. FIG. 4.—Mite traveled 151 inches in 40 minutes, or at a rate of 3.78 inches per minute. FIG. 5.—Mite traveled 106.5 inches in 30 minutes, or at a rate of 3.55 inches per minute. FIG. 6.—Mite traveled 87 inches in 30 minutes, or at a rate of 2.9 inches per minute. Dotted lines indicate the direction toward the source of illumination at time of beginning of experiment. Short intersecting lines indicate points of route where the table top was revolved 180°. (Original.)

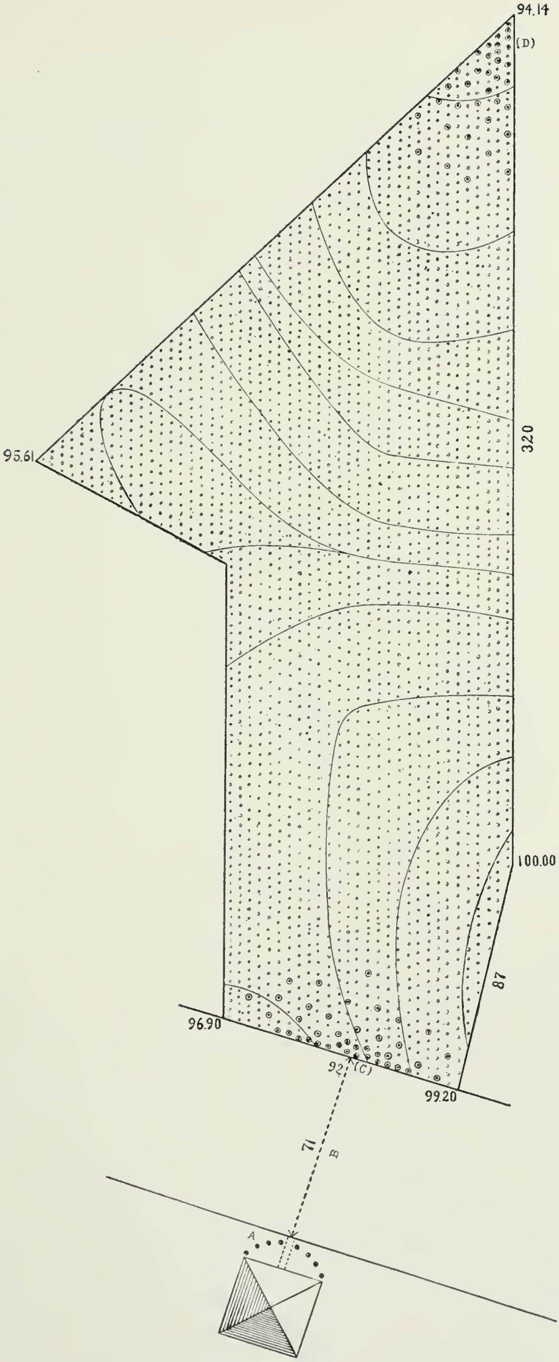


Diagram Illustrating Red-Spider Dissemination by Means of Water Dispersal.

Topographic survey map of cotton field showing contour lines and cotton rows. Red spiders traveled afoot from infested violet borders in dooryard at *A* across highway, *B*, 71 feet wide, to cotton in high end of field at *C*. From this primary infestation mites were dislodged during heavy rains and carried down the field in the surface water between the rows to the low point at *D*. Here, upon becoming stranded, they established themselves upon the cotton, giving rise to a new infestation. (Original.)

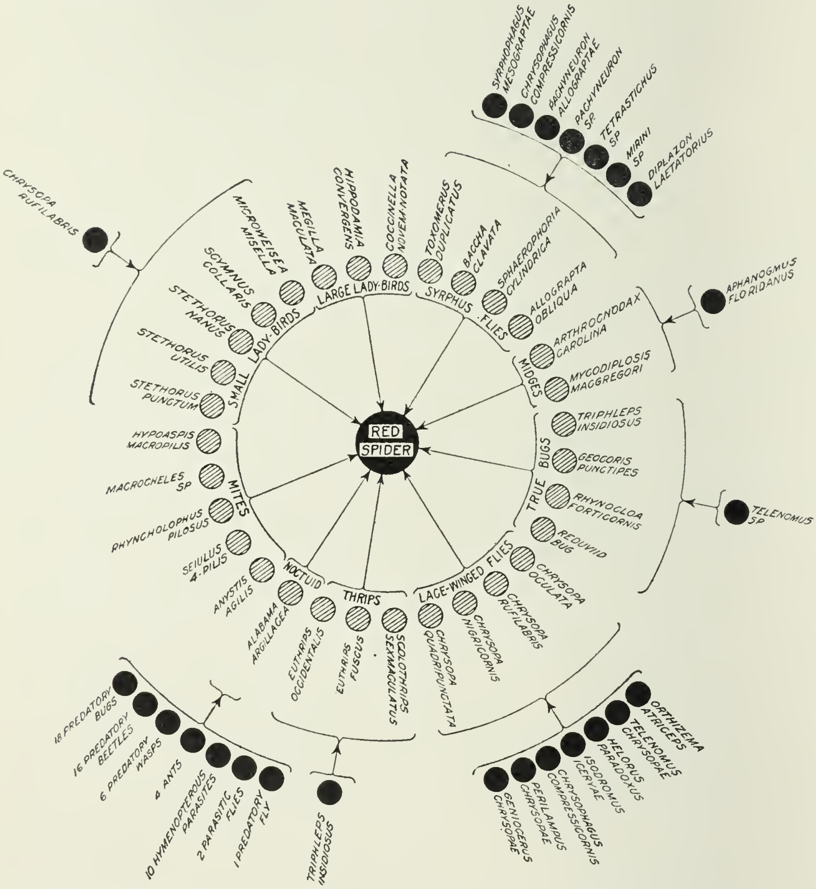


DIAGRAM ILLUSTRATING COMPLEX RELATIONSHIP OF RED SPIDER TO ITS ZOOLOGICAL ENVIRONMENT.

Nine groups of predators embracing 31 species are seen to attack the red spider, and in turn 7 of these predator groups are attacked by a total of 75 species of parasites and predators. (Original.)

INSECTA, THYSANOPTERA.

THRIPIDAE.

Scolothrips sexmaculatus Perg.—This species of thrips, as previously recorded, was mentioned by Duffey (1891) as being predacious on the red spider at St. Louis. Chittenden (1909) observed this thrips to be predatory on mites on the Kentucky coffee tree at Washington in 1906. Quayle (1913) states that he has repeatedly observed it to feed on the citrus mite, usually attacking the egg and younger spiders, and occasionally eating the adult mites. At Batesburg this thrips has been under observation during four seasons. It appears to be about the earliest predacious enemy of the red spider, having been seen on March 11, 1914, as the nymph. It becomes common in May and very abundant throughout June, July, August, and September, and has been seen as late as December 10. Upon several occasions it has been seen to attack mites in the field. The 6-spotted thrips has been observed feeding upon red spiders at the following localities: Emporia, Va.; Raleigh, Charlotte, and Laurinburg, N. C.; Clemson College, Columbia, Leesville, and Batesburg, S. C.; and Mount Pleasant, Miss. Yothers reports it actively predacious in mite colonies on velvet bean, at Orlando, Fla.

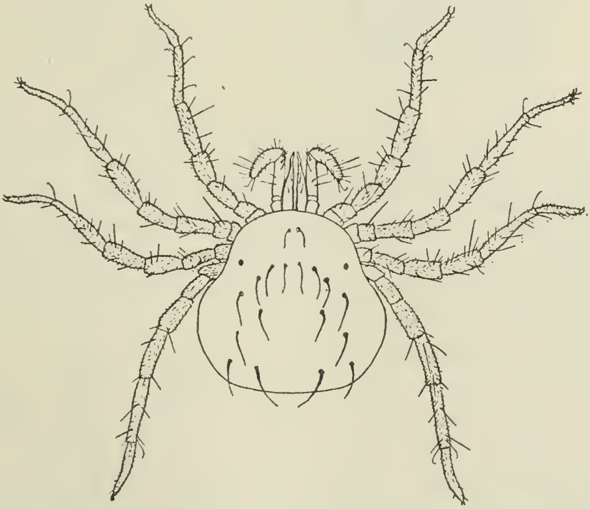


FIG. 9.—*Anystis agilis*, an enemy of the red spider. Highly magnified. (Ewing.)

A few tests were conducted for the purpose of ascertaining the capacity of this thrips for the various stages of the red spider, and data (Table VII) were secured from six specimens. These 6 thrips (all nymphs) consumed 232 eggs and 5 nymphs and adults in 10 feeding days, which gives an average consumption of 23.7 eggs and active individuals per feeding day, 98 per cent of which were eggs. It is probable that the daily average of No. 2 (Table VII), which was over 35 eggs per day, represents the normal capacity of the species.

TABLE VII.—*Red spiders consumed by Scolothrips sexmaculatus, Batesburg, S. C.*

Individual No.	Feeding days.	Consumption.			
		Eggs.	Active individuals.	Eggs and active individuals.	Average per day.
1	1	7	....	....	....
	2	2	....	9	4.5
2	1	47	....	....	....
	2	93	....	....	....
	3	18	....	....	....
	4	5	....	....	....
	[1] 5	13	....	176	35.4
3 and 4	1	8	1	9	9.0
5	1	35	....	35	35.0
6	1	4	4	8	8.0
Total 6	10	232	5	237	[2] 23.7

[1] This was first adult day.

[2] Average.

Moulton, the first investigator to establish that thrips in general are preyed upon by the insidious bug, states that *Triphleps insidiosus* is the most serious enemy of thrips. Quaintance also states that thrips, in addition to being attacked by the insidious bug, are parasitized by nematode worms. At Batesburg we find that *T. insidiosus* is very often present with Scolothrips and other thrips, and that it commonly feeds upon Scolothrips in the absence of more desirable food. The time required by Triphleps adults to drain a thrips averages about 2½ minutes. A half-grown chrysopid larva was observed to grasp and drain a nymphal thrips in 1 minute 35 seconds, and immediately seized other thrips, repeating the operation.

Euthrips fuscus Hinds.—This thysanopteron, while frequently collected in red-spider colonies, has not been observed in the act of devouring red spiders; but our observations and those of other workers indicate that this species is also an occasional enemy of the mites.

Euthrips occidentalis Perg.—This species has also been seen from time to time in red-spider colonies. The evidence concerning it is not absolute, but it is believed to be, like the two foregoing thrips, a predatory species.

HEMIPTERA.

ANTHOCORIDAE.

Triphleps insidiosus Say.—This predacious bug (fig. 10) seems to have been first recorded as a natural enemy of the red spider by the senior author in an earlier (1912) circular. Since then it has been recorded as predatory on the common red spider by Quayle (1913) and Ewing

(1914); and Parker (1913) states that a closely allied species, *T. tristicolor*, was the most numerous red-spider enemy in the hop fields, but that no controlling effect could be detected.

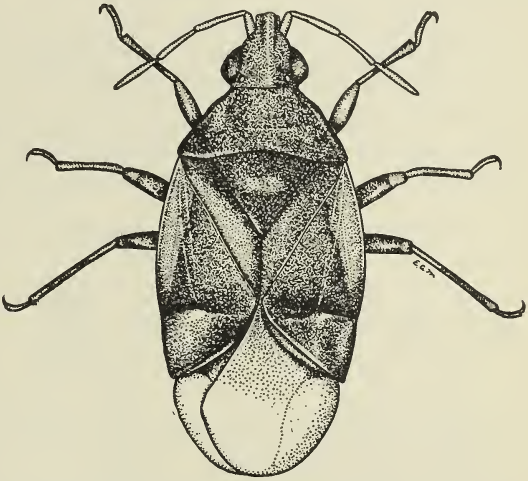


FIG. 10.—*Triphleps insidiosus*, an important enemy of the red spider: Adult. Much enlarged. (McGregor).

This predator, coming upon a red spider like a flash, thrusts its sharp proboscis through the mite's back and siphons out the body contents. In the case of one bug, the first mite was drained in about five minutes, but each succeeding meal was of shorter duration, so that the average time required for each meal was found to be about three minutes. The actions of the nymph (fig. 11) are similar. Both adults and nymphs feed upon the mites in all stages from egg to adult, but the Triphleps adult will not ordinarily consume mite eggs unless other food is scarce. The operation of draining an egg requires about two minutes.

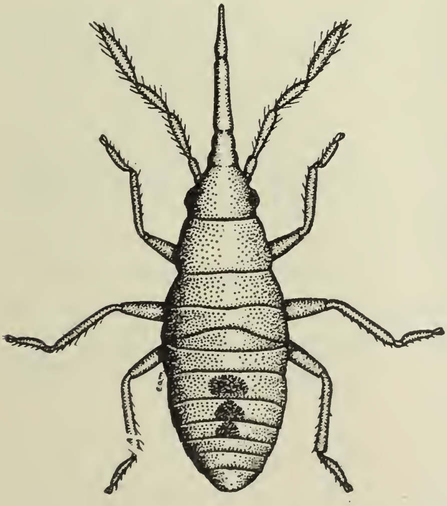


FIG. 11.—*Triphleps insidiosus:* Nymph. Greatly enlarged. (McGregor.)

These bugs pass the winter in the adult stage and usually become active some time in April, although they have been seen as early as the middle of March. Triphleps becomes extremely abundant by the first of July, and assists greatly in the reduction of the red spiders. Although it seeks hibernation toward the end of October, individuals are commonly seen some years as late as the middle of this month.

By referring to Tables VIII and IX it will be seen that 8 individuals collected as various instars of the nymph drained 1,856 red spiders in 57 feeding days. The average daily consumption of the nymph was 33.16 mites, that of the adult was 28.88, and the daily average for all individuals was

32.56 mites. The predatory capacity of the first instar is not known, since we have never reared individuals from the egg. The second nymphal instar consumes on an average 80.5 mites, the third instar consumes 112, and the fourth averages 146 between molts. The average duration of the second instar is found to be 3.22 days, that of the third instar 2.66 days, and the fourth instar requires 4.36 days. The maximum recorded consumption for one day was 68 adult mites. Moulton states that in California the life cycle of *T. insidiosus* requires only 15 days, but the foregoing data would indicate that in the Southeast a little longer period is required.

TABLE VIII.—*Predatory activity and development of Triphleps insidiosus, Batesburg, S. C.*

Individual No.	Feeding days.	Stage of predator.		Mites consumed.	Total consumption.	Remarks.
		Nymph.	Adult.			
1	1	×	....	43	176	Collected as young nymph; molted after 3 days to adult.
	2	×	....	56		
	3	×	....	30		
	4	....	×	24		
	5	....	×	23		
2	1	×	....	25	167	Collected as nymph; molted after 5 days to adult.
	2	×	....	39		
	3	×	....	29		
	4	×	....	28		
	5	×	....	15		
	6	....	×	31		
3	1	×	....	24	144	Do.
	2	×	....	33		
	3	×	....	20		
	4	×	....	24		
	5	×	....	19		
	6	....	×	21		
4	1	×	....	22	179	Collected as nymph; molted after 6 days to adult.
	2	×	....	31		
	3	×	....	34		
	4	×	....	12		
	5	×	....	42		
	6	×	....	12		
	7	....	×	26		
5	1	×	....	17	297	Collected as very young nymph in beginning of 2d instar; molted on 4th day; molted on 7th day; molted on 11th day to adult.
	2	×	....	7		
	3	×	....	25		
	4	×	....	32		
	5	×	....	47		
	6	×	....	34		
	7	×	....	55		
	8	×	....	18		
	9	×	....	29		
	10	×	....	33		
6	1	×	....	57	57	Nymph escaped.
7	1	×	....	13	438	Very small nymph at collection; molted on 4th day; molted on 6th day; molted on 10th day to adult.
	2	×	....	36		
	3	×	....	16		
	4	×	....	60		
	5	×	....	38		
	6	×	....	43		
	7	×	....	68		
	8	×	....	63		
	9	×	....	39		
	10	....	×	37		
	11	....	×	25		
8	1	×	....	17	398	Collected as very young nymph, possibly molted once; molted on 4th day; molted on 7th day; molted on 10th day.
	2	×	....	33		
	3	×	....	28		
	4	×	....	18		
	5	×	....	35		
	6	×	....	28		
	7	×	....	62		
	8	×	....	43		
	9	×	....	34		
	10	×	....	59		
	11	....	×	41		
Total...	57	49	8	....	1,856	

SUMMARIES.

Average daily consumption per nymph	33.16
Average daily consumption per adult	28.88
Average daily consumption per bug for all individuals	32.56
Duration of second nymphal instar	3.22
Duration of third nymphal instar	2.66
Duration of fourth nymphal instar	4.36

TABLE IX.—*Consumption of red spiders by each instar of Triphleps insidiosus, Batesburg, S. C.*

Individual No.	Consumption for 2d instar.	Consumption for 3d instar.	Consumption for 4th instar.
	Mites.	*Mites.*	*Mites.*
1	....	....	120
2	....	....	129
3	....	....	153
4	....	....	136
5	....	113	135
6	65	98	213
7	96	125	136
Average..	80.5	112	146

The occurrence of *T. insidiosus* on mite-infested leaves is recorded from Emporia, Va.; Raleigh, Charlotte, Greensboro, Wilmington, and Buies, N. C.; Leesville, Spartanburg, Clemson College, Batesburg, and other points in South Carolina; Macon and Savannah, Ga.; Tallahassee, Fla.; Girard, Ala.; and Meridian, Miss.

LYGAEIDAE.

Geocoris punctipes Say.—This hemipteron has not previously been considered in literature as a mite predator. Heidemann states that little is known about its life history. Observations at Batesburg are confined to the season of 1914, *G. punctipes* having been detected during August of that year. Eggs, seen in the midst of red-spider colonies on cotton leaves, were collected for rearing, and immediately upon hatching certain of the nymphs were placed in isolated cells with red spiders and their eggs. It was found that the newly hatched nymphs readily devoured the red spiders as well as some of the eggs. The egg of *G. punctipes* is cylindrical and elliptical in shape, fluted, of a pale amber color, and is deposited in the center of the mite colonies. Table X presents the data we have secured on the life history.

TABLE X.—*Life history of Geocoris punctipes, Batesburg, S. C.*

Individual No.	Collected.	Hatched.	First molt.	Second molt.	Third molt.	Fourth molt.	Incubation period (days).[1]	First instar (days).	Second instar (days).	Third instar (days).	Fourth instar (days).	Period collected to adult (days).
1	Aug. 8	Aug. 14	Destroyed				6					
2	do	Aug. 11	Aug. 16	Aug. 21	Lost		3	5	5			
3	Aug. 10	Aug. 13	Aug. 22	Aug. 25	Sept 2	Sept. 9	3	9	3	8	7	30
4	do	Aug. 14	Destroyed				4					
5	do	do	do				4					
6	do	Aug. 13	do				3					
7	do	do	do				3					
8	Aug. 26	Aug. 28	do				2					
9	do	Aug. 31	do				5					
	Averages						3.66	7	4	8	7	30

[1] Since the date of deposition of the eggs was not known, our records for incubation are all a trifle short.

It will be seen that the average time required for incubation is about 4 days, that the first nymphal instar requires from 5 to 9 days, the second instar from 3 to 5 days, the third instar 8 days, the fourth instar 7 days, and that the period from deposition to adult is doubtless about 30 days. Table XI presents our data relative to the capacity of this hemipteron as a red-spider enemy.

TABLE XI.—*Record of red spiders devoured by reared nymphs of Geocoris punctipes, Batesburg, S. C.*

Day.	Red spiders consumed by—				Day.	Red spiders consumed by—			
	Nymph No. 1.	Nymph No. 2.	Nymph No. 3.	Total.		Nymph No. 1.	Nymph No. 2.	Nymph No. 3.	Total.
1st	[1] 30	8	7		18th		95		
2d	[1] 3	5	23		19th		80		
3d	23	13	20		20th		70		
4th	30	20	29		21st		98		
5th	35	23	8		22d		114		
6th	22	43	33		23d		106		
7th	21	34	40		24th		50		
8th	31	12	50		25th		103		
9th	42	38	52		26th		111		
10th	38	52	21		27th		[2] 83		
11th	54	43	37						
12th	69	31	69						
13th		67	56		Total red spiders	398	1,589	505	2,492
14th		84	60		Total days	12	27	14	53
15th		63							
16th		65							
17th		78			Average per day (red spiders)	33.2	58.8	36.1	47.0

[1] These 33 were eggs, the diet being changed on the following day to mites.
[2] Nymph became adult on the twenty-seventh day.

From Table XI it is seen that 3 individuals with a total of 53 feeding days ate 2,492 red spiders, or an average of 47 per nymph. The first instar consumed, on an average, 141 adult red spiders; 161 were drained by the second instar, 602 by the third, and 665 mites were eaten by the fourth instar. The adults exhibited an average consumption of 83 mites per day. Although a number of eggs were eaten, Geocoris did not seem to take readily to a diet of mite eggs.

In the course of the experiments with this red-spider enemy it developed that a certain percentage of its eggs are parasitized. A scelionid, *Telenomus* sp., was reared from eggs collected in the field and required a developmental period of 11 days.

CAPSIDAE.

Rhinacloa forticornis Reuter. A nymph of this bug about two-thirds grown was observed in red-spider colonies in a cotton field, actively feeding on mites. It was transferred to a rearing cell and kept under close observation. The bug showed a strong liking for red spiders and developed to adult in the cell. Table XII contains the record of this individual.

TABLE XII.—*Consumption of red spiders by Rhinacloa forticornis, Batesburg, S. C.*

[Nymph collected Oct. 2, 1914.]

First day (molted Oct. 3)	60
Second day	72
Third day	71
Fourth day	65
Fifth day	61
Sixth day	67
Seventh day (molted Oct. 9)	46
First adult day	39
Total	481
Total feeding days	8
Average per day	60. 1
Total consumption by last instar	382

In eight feeding days this capsid bug ate 481 red spiders, or an average of 60 mites per day. Two molts occurred during the observations, the final nymphal instar lasting six days and requiring, before completion, the additional consumption of 382 adult mites.

REDUVIIDAE.

A species of reduviid bug was seen commonly on infested leaves during August and September at Batesburg. Both the eggs and nymphs were abundant at times in and about red-spider colonies on tomato leaves. An egg collected August 10, 1914, hatched August 12 and the nascent nymph was immediately placed into a breeding cell with red spiders. Seven mites were eaten the first day, 14 the second, 7 the third, 6 the fourth, 17 the fifth, 22 the sixth, and 18 the seventh. A total of 88 red spiders were destroyed in seven days, making an average of 12.6 per day.

NEUROPTERA.

CHRYSOPIDAE.

Four species of lacewing flies have been collected during the investigation at Batesburg. Lacewing flies are frequently seen on cotton leaves associated with common red spiders. Only one species, *Chrysopa rufilabris* Banks, is very abundant in South Carolina.

Chrysopa rufilabris Banks.—This species appears in late spring or early summer, the earliest record being May 6, 1914, on which date eggs and larvæ were seen. Together with the thrips, this chrysopid appears to be the earliest red-spider enemy. When an early season prevails, this predator becomes abundant about the middle of June, but, as a rule, this does not take place until July. It is not as hardy as are some of the more coriaceous enemies of the red spider, and seeks winter quarters comparatively early in the season. In fact, the species reaches its optimum development during August, and is rarely seen in any stage later than September 25. This red-spider enemy is recorded from Emporia, Va.; Wilmington, Greensboro, Charlotte, Buies, and Laurinburg, N. C.; Spartanburg, St. Matthews, Leesville, Batesburg, and numerous points in South Carolina; Savannah, Ga.; Tallahassee, Fla.; Girard, Ala.; and Dallas, Tex.

At certain times during the season *Chrysopa rufilabris* has been seen to exert marked control of the red spider, and its value as an enemy of the cotton red spider can hardly be overestimated. During June, 1914, from the 10th to the 22d, lacewing-fly larvæ were abundant, crawling in myriads on tree trunks, the ground, the ceilings of porches, and similar positions. At these times man experiences much annoyance from the mandibles of larvae which drop from piazza ceilings.

Tables XIII, XIV, and XV present data on the life history of *Chrysopa rufilabris*.

TABLE XIII.—*Egg period of Chrysopa rufilabris, Batesburg, S. C.*

Individual No.	Egg collected.	Hatched.[1]	Incubation period.
			Days.
1	June 8	June 11	3
2	July 15	July 18	3
3	July 15	July 18	3
4	Aug. 3	Aug. 8	5
5	Aug. 3	Aug. 8	5
6	Aug. 9	Aug. 13	4
	Average		4

[1] These 6 rearings are the longest of a large series and probably represent about the normal period for this stage.

Table XIV.—*Larval period of Chrysopa rufilabris.* (*Individual No. 1.*)

Hatched,	Aug. 3
Pupated	Aug. 22.
Length of larval period	18 days.

No. 4 of Table XVI was the only larva which was reared through from egg to pupa, and, as will be seen, the entire mite consumption for the individual was also secured. The larval period is 18 days, which is a trifle shorter than Davidson secured from his data based on 2 individuals. No attempt was made to determine the duration of the larval instars, but incidentally the length of the first instar was established as about 4 days. Table XV presents statistics on the pupal stage of *Chrysopa rufilabris.*

Table XV.—*Records of the pupal period of Chrysopa rufilabris, Batesburg, S. C.*

Individual No.	Pupated.	Issued.	Pupal period.	Average pupal period.	Individual No.	Pupated.	Issued.	Pupal period.	Average pupal period.
			Days.	*Days.*				*Days.*	*Days.*
1	June 9	June 17	8	8.6	8	July 26	Aug. 4	9	8.6
2	do.	do.	8		9	Aug. 3	Aug. 15	12	
3	July 8	July 15	7		10	Aug. 14	Aug. 21	7	
4	July 10	July 17	7		11	Aug. 18	Aug. 25	7	
5	July 22	Aug. 2	11		12	Aug. 25	Sept. 2	8	
6	July 23	Aug. 1	9		13	Sept. 3	Sept. 16	13	
7	July 24	do.	8		14	Sept. 9	do.	7	

From these 14 pupal records it is seen that the duration of the transformation period at Batesburg varies from 7 to 13 days, with 8.6 days as the weighted average. Thus, exclusive of a possible preoviposition interval, we find that the cycle of the chrysopid from the deposition of the egg to the issuance of the adult is about 30 days, approximating 4 days for the egg stage, 18 days for the larva, and 8.6 days for the pupal stage. In the Southeast there are probably four generations of lacewing flies in a season.

Table XVI.—*Rate of destruction of red spiders by the larva of Chrysopa rufilabris.*

Larva No.	Hatched.	Red spiders consumed.											
		1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	11th day.	12th day.
	1914.												
1	July 17	18	(1)	......	......	......	......	......	......	......	......	......	......
2	July 18	31	32	33	34	48	23	......	(2)	......	......	......	......
3	do	26	16	43	30	51	40	84	......	......	(3)	......	......
4	Aug. 3	9	28	14	29	30	37	26	41	39	48	59	63
5	Aug. 8	24	37	35	(1)	......	......	......	......	......	......	......	......
6	July 15	19	29	35	39	39	17	39	(2)	......	......	......	......
7	July 16	21	27	20	18	33	26	21	15	......	(2)	......	......
8	July 19[4]	......	......	......	......	......	......	......	......	47	62	58	66
9	do.[4]	......	......	......	......	......	......	......	......	......	56	59	69
10	Aug. 22[5]	......	......	......	......	......	......	......	......	......	......	......	......
11	Aug. 18[6]	......	......	......	......	......	......	......	......	......	......	......	......
12	Aug. 14[7]	......	......	......	......	......	......	......	......	......	......	......	......
13	Aug. 20[5]	......	......	......	......	......	......	......	......	......	......	......	......

[1] Dead.

[2] Lost.

[3] Entangled.

[4] Collected as half-grown larva.

[5] Collected as two-thirds-grown larva.

[6] Collected as mature larva

[7] Collected as large larva.

TABLE XVI.—*Rate of destruction of red spiders by the larva of Chrysopa rufilabris*—Con.

Larva No.	Hatched.	Red spiders consumed.							Pupated.	Length of larval period.	Feeding days.	Total feeding days.
		13th day.	14th day.	15th day.	16th day.	17th day.	18th day.	Total for larval period.				
	1914.											
1	July 17										1	86
2	July 18										6	
3	do										7	
4	Aug. 3	77	99	110	224	119	198	1,250	Aug. 22	18	18	
5	Aug. 8										3	
6	July 15										7	
7	July 16										8	
8	July 19[1]	75	101	113	199	122	203		July 30		10	
9	do.[1]	58	117	147	220	116	207		Aug. 29		9	
10	Aug. 22[2]	80	106	130	156	170	211		do		6	
11	Aug. 18[3]					127	188		Aug. 21		2	
12	Aug. 14[4]			145	189	129	193		Aug. 19		4	
13	Aug. 20[2]		98	129	219	130	208		Aug. 26		5	

[1] Collected as half-grown larva.
[2] Collected as two-thirds grown larva.
[3] Collected as mature larva.
[4] Collected as large larva.

In summarizing Table XVI it is found that 6,956 adult red spiders were consumed by 13 Chrysopa larvæ in 86 feeding days, or an average daily consumption of about 81. The one larva for which complete data are recorded consumed altogether 1,250 mites. The largest daily feeding was 224 mites. As the larva grows the appetite increases remarkably so that an individual which ate only 20 mites per day following hatching will consume ten times that number just prior to pupation. Larvæ numbers 8, 9, 10, 11, 12, and 13 were collected in the field in various stages of maturity, so that only the feeding of the final days can be shown. It is probable that the figures consistently represent the normal activity of this species as a red-spider eradicator. The appetite for mite eggs was not determined, but we have often seen larvæ in the act of devouring them. Probably numerous eggs were eaten along with the mites in all the foregoing records. Three minutes appears to be the average time required by larvæ in devouring a mite.

We have followed the process of the fabrication of the cocoon of *Chrysopa rufilabris* from beginning to end. Working in a looped attitude, the successive layers of silk are secreted from the tip of the abdomen, which is moved shuttle-like from side to side. Contrary to long-accepted belief, it has been established that the circular lid, which permits the exit of the adult fly, is prepared by the larva as the last act before entering the resting stage.

During the four seasons of our investigations at Batesburg it has been determined that a considerable percentage of mortality to chrysopids arises through parasitism. The results of a series of studies on lacewing-fly parasites has been published. (McGregor, 1914.) In a series of 99 cocoons collected in the field, 48 yielded parasites, thus indicating a parasitism of 48.4 per cent. Of a series of 93 chrysopid eggs, 7 were parasitized, which represents an egg parasitism of 7.5 per cent. The total parasitism, from species issuing from the egg and from species issuing from the cocoon, is computed at about 55.9 per cent. These parasites, as identified by J. C. Crawford, are as follows. Reared from cocoon: *Chrysopophagus compressicornis* Ashm., *Perilampus chrysopae* Crawford, *Geniocerus chrysopae* Crawford, *Isodromus iceryae* How., *Orthizema atriceps* Ashm. and *Heloris* sp. Reared from egg: *Telenomus chrysopae* Ashm.

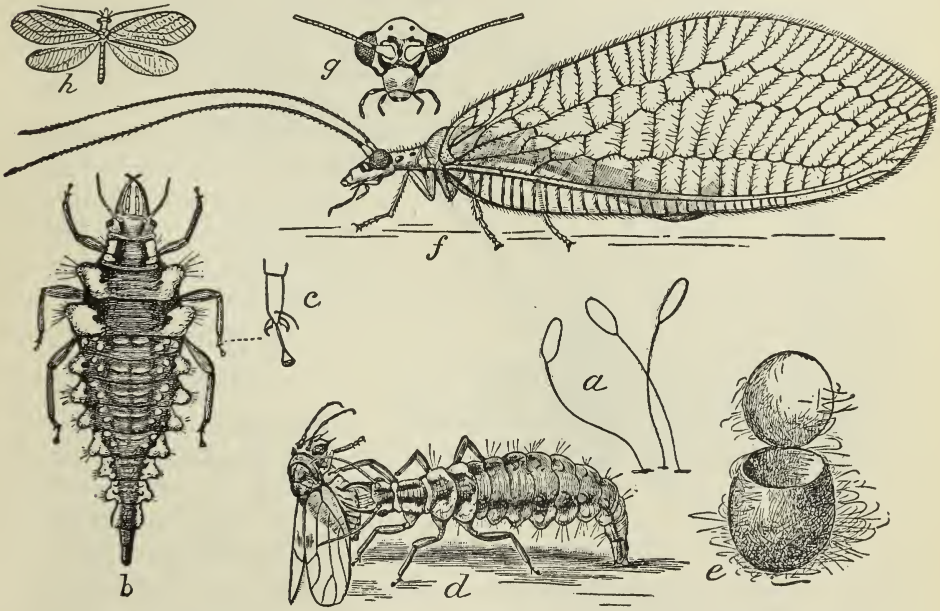


FIG. 12.—The golden-eyed lacewing fly (*Chrysopa oculata*): *a*, Eggs; *b*, full-grown larva; *c*, foot of same; *d*, larva devouring an insect; *e*, cocoon; *f*, adult insect; *g*, head of same; *h*, adult, natural size. All enlarged except *h*. (Marlatt.)

Table XVII presents our data relative to the parasitism of chrysopid eggs by *Telenomus chrysopae*.

TABLE XVII.—*Parasitism of chrysopid eggs by Telenomus chrysopae Batesburg, S. C.*

Individual No.	Egg collected.	Host.	Parasite issued.	Interval from collection to issuance.
				Days.
1	July 10, 1914	Cotton	July 13, 1914	3
2	do	Clematis	July 19, 1914	9
3	July 11, 1914	Cotton	do	8
4	July 15, 1914	Elm	July 23, 1914	8
5	do	Cotton	July 20, 1914	5
6	July 17, 1914	do	July 24, 1914	7
7	do	Clematis	July 26, 1914	9

During 1914 chrysopids were particularly abundant. They were in fact the most common predatory species. The "stalked" eggs were everywhere in evidence and the adults, which are nocturnal, rose in swarms from under the foliage as one brushed through the cotton rows.

Chrysopa quadripunctata Burm.—This species is also fairly common in the Southeast. It is most noticeable during July and August, and its larva doubtless contributes to the predatory work of *Chrysopa rufilabris.*

Chrysopa oculata Say.—Adults of this lacewing fly (fig. 12) have been reared from larvæ actively feeding on red spiders. It is not particularly common in South Carolina, however, and as a red spider enemy probably is not of primary importance.

Chrysopa nigricornis Burm.—This species has been reared on a few occasions from larvæ collected on cotton infested with red spiders. Its status is probably about the same as that of *C. oculata.*

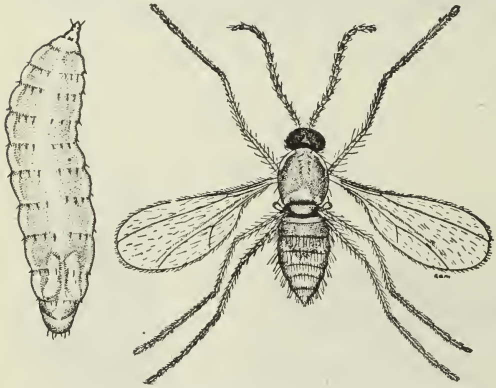


FIG. 13.—*Arthrocnodax carolina*, a predacious enemy of the red spider. At left, mature predacious larva, magnified 60 times; at right, adult female, greatly enlarged. (McGregor.)

DIPTERA.

ITONIDIDAE.

Arthrocnodax carolina Felt.—This midge (fig. 13, at right) was recognized, early in the investigation, as one of the most important enemies of the red spider, at times ranking first. Its attack is almost entirely confined to the eggs of the red spider, but an occasional mite is destroyed. The earliest seasonal record of occurrence is April 30, 1914. It is first seen usually about the early part of May and becomes abundant during the middle of May. This species does not usually reach its highest development until August, although a large amount of control work is evident during July. Arthrocnodax is always to be seen during September, sometimes commonly in large mite colonies, but becomes rare in October, during which month usually only pupæ can be seen. This important predator has been collected in mite colonies at Chase City and Emporia, Va.; Charlotte, Wilmington, Laurinburg, and Buies, N. C.; Allendale, Anderson, Batesburg, Brownsville, John's Island, Leesville, St. Matthews, and other points in South Carolina; Macon and Savannah, Ga.; Orlando, Fla.; Girard, Albertville, and Boaz, Ala.; and Tallulah and Mound, La.

Several larvæ of this midge of various sizes were collected in the field and reared to adult on mite eggs and mites. Table XVIII presents the data which bear on the larval period.

TABLE XVIII.—*Duration of the larval stage of Arthrocnodax carolina, Batesburg, S. C.*

Individual No.	Larva collected.	Condition at collection.	Pupated.	Interval from collection to pupation.
				Days.
1	Sept. 28, 1914	One-half grown	Oct. 1	3
2	Oct. 7, 1914	Small	Oct. 9	2
3	do	do	do	2
4	Oct. 8, 1914	Nascent (?)	Oct. 13	5
5	do	Very small	Oct. 11	3
6	Oct. 10, 1914	Large	do	1
7	Oct. 11, 1914	do	Oct. 12	1
8	Oct. 13, 1914	Two-thirds grown	Oct. 14	1
9	Oct. 21, 1914	Nascent (?)	Oct. 26	5
10	Oct. 26, 1914	Small	Oct. 29	3
11	do	Rather large	Oct. 28	2
12	Oct. 27, 1914	Nascent (?)	Nov. 1	5

Probable larval period, 5 days.

From the foregoing records it may be seen that very small individuals completed their larval development in from three to five days. Since several of these gave every evidence of being newly born at the time of collection and had no appearance of having fed, it is evident that some of our records represent the entire larval period. The larva (fig. 13, at left) is a small, glistening, amber-yellow grub with a pointed, protractile head which bears a pair of retractile, snail-like tentacles. A series of larvæ measured: Length, 1.5 mm.; width, 0.33 mm.

Table XIX includes the completed records on the duration of the pupal stage which are available.

TABLE XIX.—*Duration of the pupal period of Arthrocnodax carolina, Batesburg, S. C.*

Individual No.	Larva pupated.	Adult issued.	Pupal period.
			Days.
1	Oct. 8.	Oct. 15.	7
2	Oct. 10.	Oct. 18.	8
3	Oct. 11.	Oct. 19.	8
4	do	Oct. 20.	9
5	Oct. 12.	Oct. 21.	9
6	do	Oct. 20.	8

Average pupal period, 8.2 days.

The data contained in Table XIX obtained from October rearings indicate that the pupal period of this predator under summer conditions does not exceed eight days, and at times may be a trifle less.

The cocoon (fig. 14) is elliptical, whitish (except in the case of the wintering pupæ), 1 mm. in length by 0.55 mm. wide, and is spun on the underside of the leaf in the protecting angles of the midveins, etc. (fig. 14). In selecting a site for the cocoon the larva incloses within the preliminary fibrils two or three mite eggs, presumably for nourishment while spinning the cocoon. A larva was seen to attach a fibril deftly to the dorsal bristles of an adult female that happened to wander in among the guy-fibrils of the cocoon. "Staked out" in this manner the female remained tethered long enough to deposit two eggs in the precise position suitable to the convenience of the spinning larva. No effort is made, apparently, to conceal the summer cocoons, but the overwintering cocoons are designed with the idea of concealment. Specimens of the latter type are very inconspicuous, owing to the fact that they assume almost the exact color shade of the surface upon which they are constructed.

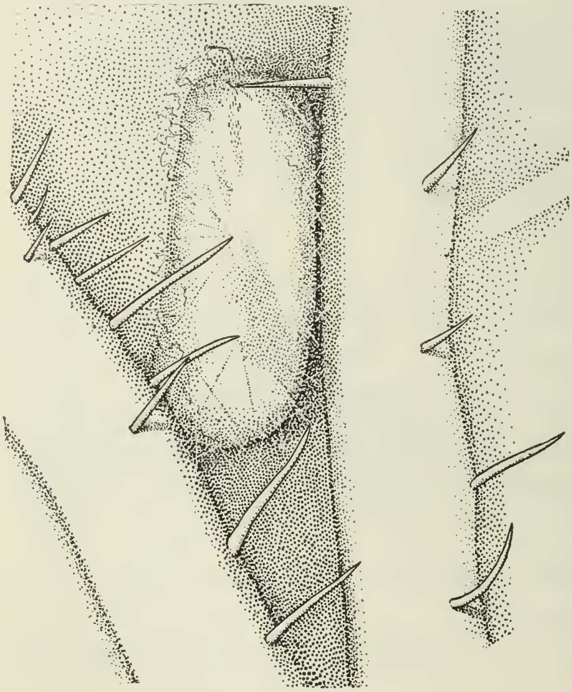


FIG. 14.—Cocoon of *Arthrocnodax carolina* on underside of violet leaf. (Drawn by camera lucida.) (Original.)

Assuming the incubation period to be about 3 days (as is the case with certain similar forms), with 5 days for the larval stage and 8 days for the pupa, the entire cycle from deposition to the issuance of the adult midge will be approximately 16 days. We are inclined to believe that under optimum conditions the cycle may be completed in somewhat less time than this. Table XX presents the records of predation which we have secured.

TABLE XX.—*Consumption of red-spider eggs*[1] *by Arthrocnodax carolina, Batesburg, S. C.*

Larva No.	Collected.		Feeding.					Total consumption (eggs).	Total feeding days.	Pupated.	Average consumption per day (eggs).
	Date.	Condition.	First observed day.	Second observed day.	Third observed day.	Fourth observed day.	Fifth observed day.				
1	Aug. 29, 1914	Half grown	21	29	25			75	3	Sept. 1	25
2	Sept. 7, 1914	Small	136	19				155	2	Sept. 9	77.5
3	do	do	35	38				73	2	do	36.5
4	Sept. 8, 1914	Very minute	53	30	12			95	3	Sept. 11	31.7
5	Sept. 10, 1914	Large	42					42	1	do	42
6	Sept. 11, 1914	do	58					58	1	Sept. 12	58
7	Sept. 13, 1914	Two - thirds grown.	67					67	1	Sept. 14	67
8	Sept. 26, 1914	Small	53	38	22			113	3	Sept. 29	37.7
9	do	Rather large	51	43				94	2	Sept. 28	47
10	Oct. 27, 1914	Nascent (?)	81	30	43	40	89	283	5	Nov. 1	56.6
		Total						1,055	23		45.9

[1] In addition to eggs, some immature mites were also eaten and they are included in the daily consumption figures.

In the foregoing tests 10 larvæ ate 1,055 eggs in 23 feeding days, which yields an average daily consumption of 45.9 eggs per day. The largest number of eggs eaten in one day was 136. The fact that this species often multiplies with great rapidity is explained in part by the very short life cycle. Considering that each larva averages 46 mite eggs per day, and that as high as 52 midges have been seen on a leaf, the remarkable control exerted by this midge may be comprehended.

This predacious species is seldom observed on cotton until infestation has assumed threatening proportions, and many mites in all stages and innumerable eggs are present. As Quayle (1913) has remarked, this species more often operates in colonies which are covered with webbing, but whether this is instinctive or merely incidental would be difficult to determine. The larvæ are surprisingly agile. Coming in contact with a mite egg, the head end is instantly thrust against the shell, through which the piercing device is forced and the feeding begins. Large larvæ devour an egg in from 1 to 2 minutes, while the smaller larvæ require more time according to their size.

Arthrocnodax carolina is parasitized by the minute chalcidid fly *Aphanogmus floridanus* Ashm.

Mycodiplosis macgregori Felt.—During the season 1914 we have also detected a second itonidid species which is predacious upon the red spider. The larva of Mycodiplosis can not be distinguished in the field from that of Arthrocnodax, and the habits and life histories are doubtless much the same. This species is seemingly somewhat later than Arthrocnodax, being occasionally found at Batesburg as late as early December. No special experiments have been undertaken to determine the egg-eating capacity of Mycodiplosis, but from a few field observations we are convinced that its appetite is about the same as that of *Arthrocnodax carolina*.

SYRPHIDAE.

Quayle (1913) states that there are two or three species of syrphus-fly larvæ that eat red spiders. Ewing (1914) also records that he has seen them feeding on the mites in hop fields. However, we find no records of any of these having been reared or specifically identified.

At Batesburg syrphus flies are found in all stages in cotton fields from the last of May until the 1st of September, and are most abundant during July and August. They are incidental enemies of the red spider, and are more intent upon the capture of aphids and insects more conspicuous than mites. However, they are often seen crawling through red-spider colonies, and upon a few occasions have actually been seen to devour adult mites.

Baccha clavata Fab.—This dark-colored, wasplike syrphid was apparently the commonest species. The larvæ and the large, flesh-colored puparia could always be found through the midsummer on cotton infested with aphids and mites. A larva was seen to grasp and devour a female red spider in an interval of 2 or 3 seconds. Table XXI gives statistics on red-spider consumption gathered from tests with larvæ of *Baccha clavata* collected in the field in various stages of development.

TABLE XXI.—*Red-spider consumption by larvæ of Baccha clavata, Batesburg, S. C.*

Individual No.	Consumption of mites.[1]											
	1st day.	2d day.	3d day.	4th day.	5th day.	6th day.	7th day.	8th day.	9th day.	10th day.	Feeding days.	Total mites eaten.
1	19										1	19
2	70	[2] 56									2	126
3	60	33	47	2	26	13	21	27	20	4	10	253
4	20										1	20
5	13	10	9								3	32
Total											17	450

[1] Fed with adult mites but many mite eggs were also eaten.

[2] Pupated.

It will be seen that 5 larvæ of *Baccha clavata* in 17 feeding days consumed 450 adult red spiders, which gives an average of 26.5 mites per day.

Allograpta obliqua Say.—This medium-sized syrphus-fly, with abdomen alternately banded with sulphur yellow and chocolate brown, probably ranks second in abundance among these flies. Its larvæ are seen commonly in fields during August.

Sphaerophoria cylindrica Say.—Although a trifle smaller, this syrphid (fig. 15) resembles the preceding species superficially. The small, parchment-like puparia are frequently observed on leaves supporting active or exterminated aphid and mite colonies. They become very common toward the end of August on tomato vines infested by mites, upon which they exert marked control.

Toxomerus duplicatus Wied.—This very small, yellowish species was occasionally taken on infested cotton leaves toward late summer. Its small size would indicate, possibly, that it is better qualified as an enemy of the red spider than the larger species. Its occurrence, however, is rather limited.

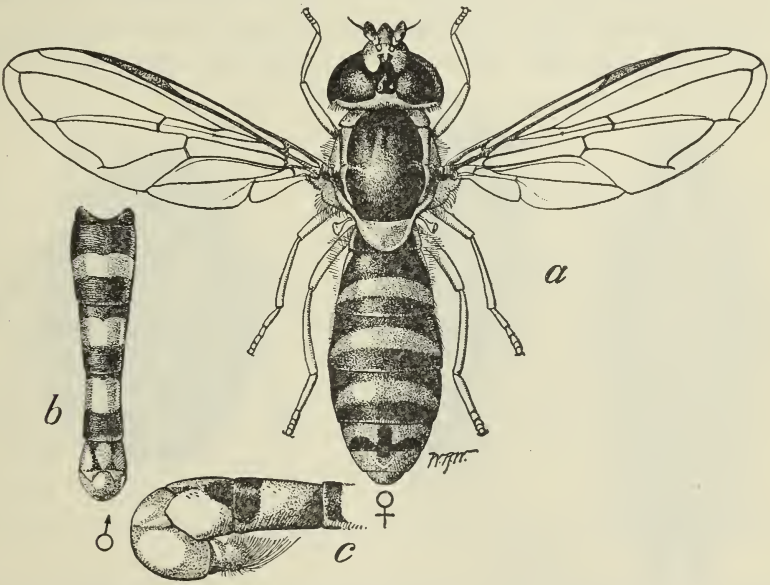


FIG. 15.—*Sphaerophoria cylindrica*, an enemy of the red spider: *a*, Female fly; *b*, dorsal view of abdomen of male; *c*, hypopygium of male, lateral view. Much enlarged. (Webster and Phillips.)

Like most of the other red-spider predators, the syrphids in turn have their enemies. In fact, they are usually well supplied with parasites, 7 species having been reared during the last few seasons. We are not in a position to furnish specific data connecting these parasites with their respective hosts, but will merely list them collectively as enemies of the four syrphid species. They are: *Chrysopophagus compressicornis* Ashm., *Pachyneuron allograptae* Ashm., *Pachyneuron* sp., *Syrphophagus mesograptae* Ashm., *Tetrastichus* sp., *Diplazon laetatorius* Fab., and a species belonging to the tribe Mirini.

COLEOPTERA.

COCCINELLIDAE.

In 1893 Morgan recorded the predatory work of *Pentilia* sp., which was very effective against mites at Baton Rouge, La. Titus states that several lady-beetles were observed by him in 1905 feeding on the red spider. In 1906, at Washington, D. C., Chittenden (1909) found (*Scymnus*) *Stethorus punctum* an active enemy of the red spider on Gymnocladus. *Stethorus punctum* was also recorded in 1909 by Weldon as one of the principal red-spider enemies in Colorado. Worsham (1910) states that *Stethorus punctum* was the only predacious species observed in Georgia in the case of the cotton red spider. In the Sacramento Valley of California, Parker (1913) found *Stethorus nanus*, *S. marginicollis*, and *Pentilia* sp. present in small numbers in mite colonies. Ewing (1914) found the larvæ of *Stethorus punctum* in the Willamette Valley, Oregon, where he says they were voracious red-spider enemies. These coccinellids have been known as red-spider enemies for some time, and occur over a large part of the United States.

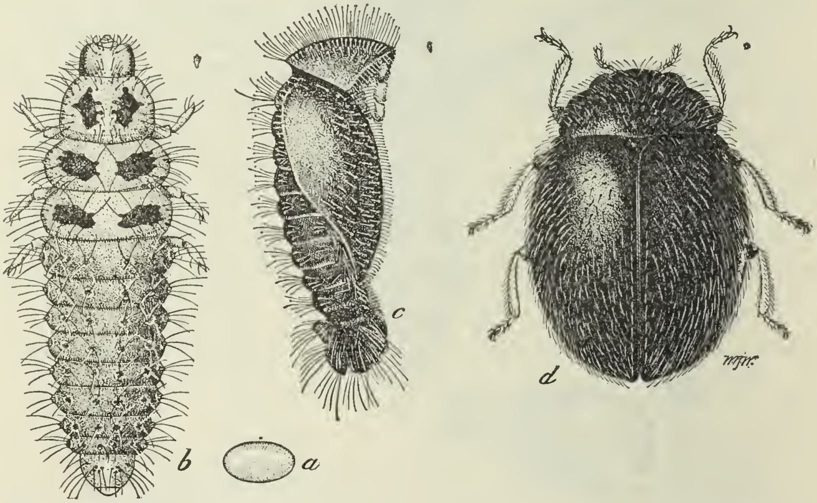


FIG. 16.—*Stethorus punctum*, an enemy of the red spider: *a*, Egg; *b*, larva; *c*, pupa; *d*, adult. All greatly enlarged. *a*, *b*, *c*, redrawn after Weldon; *d*, Webster.

Stethorus punctum Le Conte (fig. 16).—This is probably the most effectual coccinellid enemy of the red spider. We have seen it so extremely abundant on infested jack beans and jump-vine leaves that the red spider was quickly exterminated. On these host plants as many as a dozen larvæ and a dozen pupæ have been seen on a single leaf. This is the same species as that observed by J. C. Duffey (1891) to exterminate vast colonies of the red spider on Manihot, Ficus, Morus, Tilia, and Ipomœa at St. Louis in 1891. Such striking demonstrations of the economic value of the species have been seen in the field that it holds a position of greatest importance as an enemy of the red spider. Duffey records chrysopid larvæ as predacious on the pupæ of this form, and we also have observed lacewing-fly larvæ devouring the immature stages.

Stethorus utilis Horn.—This little brownish species has been observed in red-spider colonies on cotton. It is second in importance only to the preceding ladybird, and is most in evidence during July and August. An individual of this species (in the third instar) was observed to eat 3 mite eggs in 7, 7$\frac{3}{5}$, and 8 seconds. This is the fastest rate of egg destruction noted for any predator. Another individual (in the fourth instar) sucked 4 mite eggs in 28, 72, 46, and 77 seconds. Two larvæ were isolated and kept supplied with red spider eggs. One escaped, but the other was reared through to adult. Table XXII gives the life-history record of this individual.

TABLE XXII.—*Life cycle of Stethorus utilis, Batesburg, S. C. (Individual No. 1.)*

Eggs collected	July 25	Length of incubation	4 days (?)
Eggs hatched	July 29	Length of first instar	3 days
First molt	Aug. 1, 9 a. m.	Length of second instar	1$\frac{1}{10}$ days
Second molt	Aug. 2, 11.30 a. m.	Length of third instar	2$\frac{1}{6}$ days
Third molt	Aug. 4, 3 p. m.	Length of fourth instar	4$\frac{3}{4}$ days
Pupated	Aug. 9, 9 a. m.	Pupal period	4 days
Adult issued	Aug. 13, 9 a. m.	Deposition to adult	19 days (?)

Since the conditions surrounding this individual were as nearly normal as possible, it is probable that the foregoing record represents fairly the life cycle of the species.

Table XXIII contains statistics covering the entire feeding capacity of one individual of this species from hatching until adult.

TABLE XXIII.—*Consumption of red-spider eggs by Stethorus utilis.*

Hatched	July 29.
Eggs eaten:	
First day	10
Second day	14
Third day	7
Fourth day	32
Fifth day	38
Sixth day	17
Seventh day	38
Eighth day	73
Ninth day	40
Eggs eaten—Continued.	
Tenth day [1]	116
Total	385
Feeding days	10
Average daily consumption	38.5
Eggs eaten:	
During first instar	31
During second instar	32
During third instar	55
During fourth instar	267

[1] Was found pupated on eleventh day.

It will be seen that the above individual in 10 feeding days ate 385 red-spider eggs, or 38.5 eggs per day. Although this coccinellid has frequently been seen eating mites in outdoor locations, the experimental individual was confined to an exclusive egg diet, in order to ascertain if the species would develop to maturity on eggs alone. Quayle (1913) has stated that *S. picipes* larvæ ate about 7 mites per day during April in California, but that rate of feeding would doubtless become accelerated under such temperature conditions as obtained during the tests at Batesburg.

Stethorus nanus Le Conte.—This small black species has been identified from individuals collected while actively feeding in red-spider colonies. Tests have not been conducted with this coccinellid.

Scymnus collaris Melsheimer.—This species has been taken on several occasions from the midst of red-spider colonies in which they were feeding, but no data relative to its mite-feeding capacity have been secured.

Microweisea misella Le Conte.—This minute member of the lady-beetle group was collected from June to October on elderberry, phlox, and tomato, all of which were infested with the red spider. Only individuals in the adult stage were seen, but these were very active within the mite colonies. Owing to the minute size of this species, it is probable that its control capacity is rather limited.

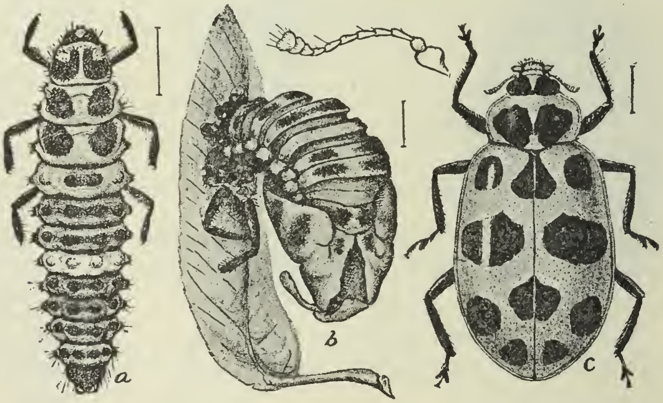


FIG. 17.—The spotted lady-beetle (*Megilla maculata*), an enemy of the red spider: *a*, Larva; *b*, empty pupa skin; *c*, adult. Much enlarged. (Chittenden.)

Megilla maculata De Geer.—A few eggs of this coccinellid (fig 17) were collected September 10, 1914, and hatched under control. One individual was reared to adult on a diet of adult mites and was identified as this species. Table XXIV contains our data relative to the life history of this lady-beetle.

TABLE XXIV.—*Life cycle of Megilla maculata, Batesburg, S. C.*

Eggs collected 1914	Sept. 10	Length of first instar	7 days
Eggs hatched	Sept. 11	Length of second instar	3 days
First molt	Sept. 18	Length of third instar	4 days
Second molt	Sept. 21	Length of fourth instar	10 days
Third molt	Sept. 25	Pupal period	6 days
Fourth molt	Oct. 5	Hatched to adult	30 days
Egg period	1 + day		

There is a larval period of 24 days, requiring 4 instars of 7, 3, 4, and 10 days, respectively, and a pupal period of 6 days, altogether embracing an interval of 30 days from hatching to the issuance of the adult.

TABLE XXV.—*Feeding capacity of Megilla maculata for red-spider adults, Batesburg, S. C. (Eggs hatched Sept. 11, 1914.)*

	Mites.
1st day	7
2d day	7
3d day	9
4th day	17
5th day	22
6th day	25
7th day (molted)	31
8th day	48
9th day	63
10th day (molted)	75
11th day	80
12th day	100
13th day	96
14th day (molted)	76
15th day	83
16th day	97
17th day	111
18th day	135
19th day	156
20th day	218
21st day	206
22d day	224
23d day	125
24th day (pupated).	
Total consumption	2,011
Average daily consumption	87.4

From Table XXV it may be seen that 1 individual in 23 feeding days ate 2,011 adult mites, thus averaging 87.4 mites per day. There are probably 3 or 4 generations of this coccinellid in a season in the Southeast.

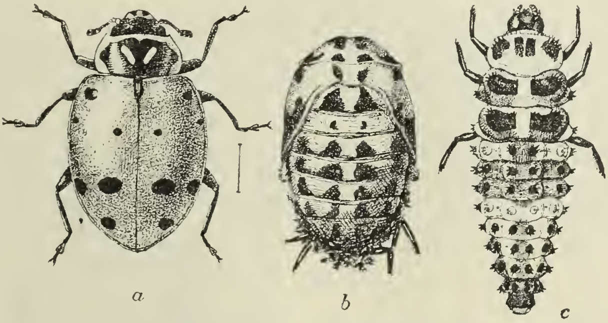


FIG. 18.—The convergent lady-beetle (*Hippodamia convergens*), an enemy of the red spider: *a*, Adult; *b*, pupa; *c*, larva. Much enlarged. (Chittenden.)

Hippodamia convergens Guérin.—This species (fig. 18) is perhaps the commonest of the ladybirds in the Southeast. We have seen it on a few occasions busily engaged in consuming the members of mite colonies. We have conducted no special tests with this beetle, either for life history or control efficiency, since we do not consider that it normally spends much of its time in the quest of red spiders. A newborn larva of this species on one occasion ate 27 adult mites in 24 hours. As compared with Miss Palmer's (1914) life-history records for this species, we obtained 3 days in 2 cases for the egg period and 7 and 8 days in 2 cases for the pupal stage, as against 3 days and 4 or 5 days, respectively, for her experiments. The fact that the summer adults of the larger lady-beetles live from 2 to 4 months (as established by Miss Palmer, 1914) makes each individual potentially of much greater economic importance. This species deposits about 400 eggs.

Coccinella novemnotata Herbst.—Next to the preceding species the

9-spotted lady-beetle (fig. 19) is probably most abundant. Its seasonal occurrence doubtless corresponds very closely with that of *H. convergens*, although our records of the latter have usually been somewhat earlier.

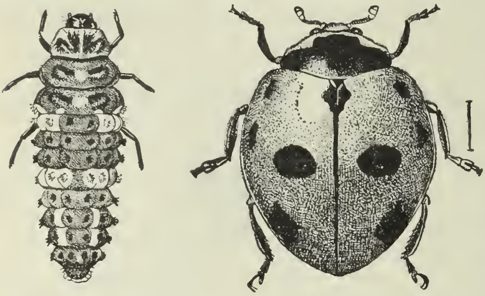


FIG. 19.—The nine-spotted lady-beetle (*Coccinella novemnotata*), an enemy of the red spider: Larva at left, adult at right. Much enlarged. (Chittenden.)

One adult individual from infested cotton ate 31 adult red spiders in 24 hours. Occasional observations have been recorded of this coccinellid feeding on red spiders in the field. At Batesburg the one record for incubation was 3 days (in August) and for the pupal period the solitary record occupied the last 10 days of August.

LEPIDOPTERA.

NOCTUIDAE.

Alabama argillacea Hübn.—When the cotton leafworm caterpillars become abundant, usually in late September or early October, they devour every vestige of the cotton foliage, excepting the stalks, branches, and petioles. Consequently myriads of red spiders which are harbored on the leaves at the time of defoliation are eaten along with the leaf tissue. In this way the leafworm acts most effectively as a remedial agency against the mites. There is an additional consideration in this connection, namely, that those mites which are not actually devoured at the time of the defoliation are compelled to seek new hosts through migration.

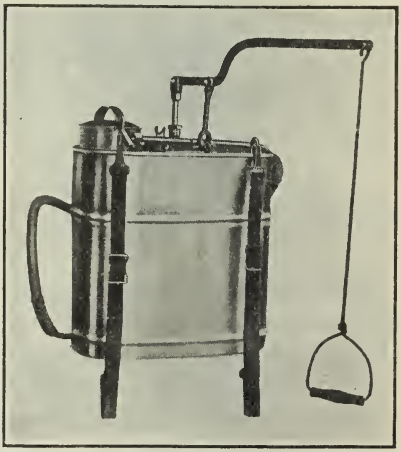


FIG. 20.—Knapsack sprayer suitable for spraying low-growing plants. (Quaintance.)

APICAL SWARMING.

At times of continued drought and heat the lower and earlier infested leaves of many plants become dry and unattractive to the red spiders, which travel upward or outward, seeking the apical leaves, that normally remain green longer. If the plant is heavily infested, a swarming horde of mites is often witnessed converging toward and concentrating at the apices of the branchlets. Upon reaching the tip of the branch or leaf they fairly overrun one another and become ensnared in the web spun by the later arrivals. In the case of the perennial pea (*Lathyrus latifolius*), the swarming continued until fully half of the area of the terminal leaflets was enveloped. A typical terminal leaflet was carefully examined and measured. The swarm was found to be built out to a thickness of 0.25 inch beyond the surface of the leaf, and all mites within the mass were dead. One such swarm was found to contain about 15,000 mites. Innumerable thousands of red spiders are eliminated in this manner.

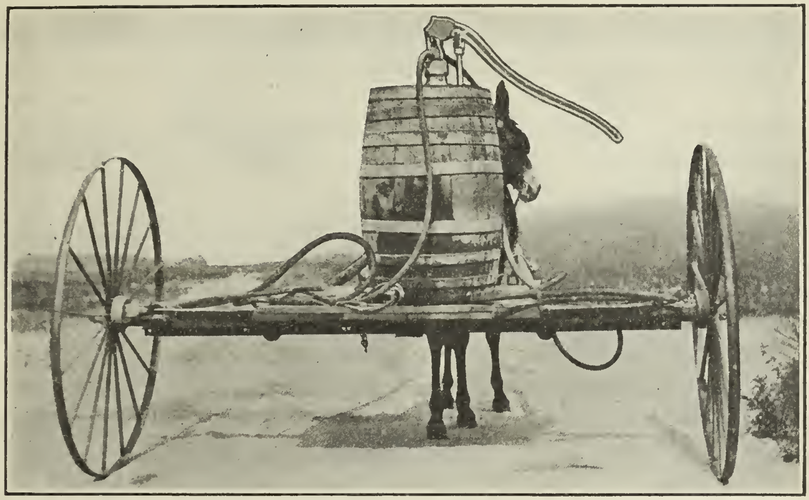


FIG. 21.—Ideal outfit for spraying cotton fields: Barrel pump with double lead of hose mounted on dismantled hayrake. (Original.)

REMEDIAL MEASURES.

PREVENTIVE.

Titus, in 1905, was the first investigator to advocate the application of cultural methods as a means of controlling the red spider. He suggested the rotation of crops, elimination of all plant, weed, and grass growth near fields during the winter and early spring, and fall or winter plowing to turn under all vegetation. Worsham (1910) also strongly recommended the destruction of all winter food plants in proximity to infested cotton fields.

We have already shown that red spiders readily establish themselves on several of the native and dooryard plants. These hosts serve as sources of dispersion. By destroying, during the winter and early spring, pokeweed, Jerusalem oak, Jamestown weed, wild blackberry, wild geranium, and other plants which breed the pest, much good will be done. This plan has been tested by the writer in several instances and has given complete immunity the following season. Ewing (1914) states that this idea was tried in hop fields in Oregon, with the result that the part of the field that was well cleared of foreign vegetation remained free of red spiders, while the neglected portion developed serious infestation. Too much emphasis can not be placed on the importance of ridding all field borders, ditch banks, terraces, etc., of all vegetation so far as possible. Pokeweed and other persistent perennials should be grubbed out.

The destruction of weeds by spraying with sodium arsenite at the rate of 1 pound to 20 gallons of water is very effective.

Many cases of infestation in urban localities can be traced back to borders of cultivated violets growing in near-by house yards. (Pl. VII.) In several instances of past severe annual infestation violets adjoining fields have been thoroughly sprayed, with the result that no red spiders appeared in these fields. The objection to this treatment is the failure on the part of the average person to persevere with the spraying until the mites have been entirely exterminated. The most satisfactory procedure consists in the removal and destruction of the violets.

Early in the investigation it appeared possible that there might be a variation in the degree of susceptibility of cotton varieties to the red spider, for in 1903 Watt and Mann stated that there was a marked difference in the susceptibility of tea (Thea) varieties in India to the Indian red spider, *Tetranychus bioculatus* Green.

During 1912, 1913, and 1914 many varieties of cotton have been planted in exposed fields and records have been made of the percentage of infestation developing in each. Paralleling these experiments data have also been gathered from many cases of infestation in South Carolina and North Carolina. In Table XXVII, which represents the relative degree of infestation of the varieties tested at Batesburg, the position of each variety is obtained by averaging the infestation percentage as exhibited by it during the several years; thus, variety No. 1 was the heaviest infested and No. 37 was the lightest.

TABLE XXVI.—*List of standard varieties of cotton, tested for susceptibility to red-spider injury, Batesburg, S. C.*

1. Lone Star.
2. Keenan.
3. Christopher.
4. Bank Account.
5. Rublee.
6. Money Maker.
7. Cook's Improved.
8. Simpkins.
9. Uncle Sam.
10. Broadwell.
11. Stone's.
12. Toole.
13. Covington-Toole.
14. Hawkins.
15. Mebane Triumph.
16. Lowe.
17. Culpepper.
18. Peterkin.
19. Excelsior.
20. Dixie.
21. Cleveland.
22. World's Wonder.
23. Russell Big Boll.
24. Hite's Prolific.
25. Bostwick.
26. King.
27. Columbia L. S.
28. Poor Land.
29. Bates.
30. Rowden.
31. Truitt.
32. Trice.
33. Shine's Early.
34. Sea Island.
35. Wade's Triumph.
36. Dongola.
37. Summerour's Half and Half.

We feel that we can say that among the cotton strains the old Peterkin group is probably most susceptible.

An experiment was conducted in testing the value of thickly broadcasting cotton at the boundary of a field as a trap crop for red spiders. The cotton was sowed between the cotton field proper and a large, heavily infested border of violets. The broadcasted cotton became infested and was plowed in before there was danger of a second migration to the crop proper. As a result the field remained free from mites. Although we do not recommend the broadcasting measures as an important method of prevention, still the success of this experiment would indicate strongly that the cotton trap crop is practicable as an auxiliary expedient to be used in controlling this pest.

It has been surmised that wide spacing of the stalks, thus preventing the interlacing of branches, would prevent the spread of the red spider through a field. Experiments at Batesburg have shown that the red spider disperses through a cotton field commonly both by means of the ground and the interlacing branches. While this shows the futility of the wide spacing as a complete preventive, it seems reasonable to suppose that the movement of the red spider will be somewhat impeded; in fact, we can corroborate this supposition to some extent in that infestation was observed to spread very slowly in certain checked fields.

Since the movements of nearly all insects, when crawling over the ground, are retarded by pulverized soil, it appeared that by maintaining a dust mulch in exposed cotton fields the progress of the migrating mites would be checked. In the case of the "check" cotton fields, it was possible to maintain continually a thoroughly pulverized soil surface. It was observed that the infestation in these fields progressed very slowly and failed to become at all threatening. In fields cultivated in checks it is easy to see that leaf-to-leaf dispersion will be greatly restricted and, at the same time, ground travel somewhat retarded. Thus, by combining these two measures—spacing the plants and maintaining a surface mulch—much good will doubtless result. In the cultural experiments conducted, both the ordinary sweep and the spring-tooth adjustable cultivator have been employed. The latter implement creates a much better surface mulch than does the old-type sweep.

Early planting permits the plants to develop a maximum growth of foliage and fruit by the time mites appear in large numbers, which is important, inasmuch as plants of considerable size are rarely killed by the pest, nor are well-advanced bolls commonly shed from red-spider infestation. Early planted cotton ages and soon toughens, making it untempting to the red spider at a time when later cotton offers ideal feeding conditions. Late cotton is almost always objectionable to the farmer, since in ordinary seasons it results in a reduction of the yield, and because of the fact that it suffers heavily in the event of the appearance in the late summer of the bollworm, or the leafworm, or of the boll weevil in western sections.

We have made an effort to establish the rotational value of the common crop plants, garden plants, and field plants, both by planting them in or near infested fields and by making frequent examinations of a great many of these plants which happened to be planted by others in infested localities. Besides cotton, we have found red spiders commonly upon the following field crops: Cowpeas, vetch, red and white clover, alfalfa, corn, hops, beets, and watermelon. They also have been found frequently upon the following garden crops: Pea, bean, onion, tomato, pepper, Irish potato, sweet potato, lettuce, okra, turnip, mustard, radish, cabbage, squash, beet, celery, strawberry, and several others. Our host list also included many of the common bush fruits, tree fruits, and dooryard plants. Rather acute cases have been seen on corn, cowpeas, and sweet potatoes. The only plants which have appeared largely immune are the grasses and the small grains. Owing probably to the lack of shelter, which the foliage of the grasses exhibits, the mites are unable to maintain themselves under severe weather conditions. The planting of grains on land normally heavily infested is therefore a measure which should be considered by the farmer.

REPRESSIVE.

That it is possible to eradicate the pest from infested fields has been demonstrated, but in many cases the task is so tedious that only the most determined farmers will resort to the necessary measures.

The experiment has been tested frequently of pulling up and destroying the first few plants which show infestation. In applying this measure the farmer must maintain a constant surveillance of suspected fields, so that the earliest affected stalks may be detected. In such cases the operation will probably have to be repeated several times, owing to the fact that certain plants are overlooked during the first examination because the colonies on them are too young to have revealed their presence. Great care should be observed in locating every plant which shows the characteristic red spots, and these must be carefully taken from the field and burned. This must be done before infestation has reached the point where there is danger of a secondary dissemination, and before there is liability of the dropping of infested leaves.

If infestation has spread until a considerable area has become involved, more drastic steps will have to be taken. It is sometimes advisable, where a continuous area of infestation occurs in a large field, to plow up all the affected portion in order to save the balance of the field. The stalks should be piled up quickly and burned with the assistance of straw or light trash. Such a severe measure, however, should be resorted to only in extreme cases, and the planter concerned must be the judge of its advisability.

Since we have established by experimentation that red spiders are unable to liberate themselves when buried 1 inch or more in soil, the importance of plowing affected areas thoroughly is evident.

INSECTICIDES.

In the course of experiments with red-spider sprays 74 different spray combinations have been tested.

Table XXVII.—*List of red-spider sprays employed with favorable results, Batesburg, S. C.*

1. Potassium sulphid.
2. Kerosene emulsion.
3. Lime sulphur (home-made).
4. Lime sulphur (manufactured).
5. A miscible oil.
6. A water-soluble oil.
7. Resin wash.
8. Nicotine sulphate and miscible oil.
9. Nicotine sulphate and fish-oil soap.
10. Fish-oil soap solution.

In addition to these successful sprays, special mention should be made of potassium permanganate. In a 2 per cent solution this is an excellent spray, but its cost is prohibitive, except in cases where only a few plants are to be treated.

SULPHUR PREPARATIONS.

Finely resublimed sulphur, both unadulterated and mixed with dehydrated lime, was thoroughly tested on infested violets, dahlias, roses, and cotton. It was applied with a dust gun during very warm weather. Heavy infestation on prostrate violets was eradicated by the sulphur dust; 60 per cent of the red spiders on dahlias were killed; 25 per cent of those on roses were destroyed; and from 1 to 15 per cent mortality occurred on 4-foot cotton. Suspecting that this variation in mortality came about through the agency of surface radiation, the following test was made: A small area of ground surface was thoroughly dusted with resublimed sulphur, and a heavily infested potted violet plant was set into the center of this area, so that no leaves touched the ground. The foliage, which had not been treated, was about 6 inches from the soil surface. Examination after 8 hours' exposure on a very hot day showed that over 99 per cent of the mites had been killed. When elevated a distance of 18 inches above the sulphured ground practically no mortality occurred to infested violets. This indicates that the heat radiated from the ground (acting on the sulphur immediately at hand) is the chief factor which determines the mortality resulting from the use of sulphur dust. We can state that this treatment (except for such very prostrate plants as violets) is not at all effective in the Southeast.

Sulphur mixed with water was sprayed on infested cotton. Examination showed that the red spiders were in no way affected. When soft soap was added to this same spray, however, the resulting mortality was from 50 to 99 per cent, depending on the thoroughness with which the preparation was kept mixed.

Potassium sulphid has been tested at strengths of from 4 ounces to 3 gallons of water to 1 ounce to 4 gallons of water on cotton, sweet peas, hollyhock, beans, and violet. The former concentration slightly damaged the foliage and a mixture of 1 ounce to 2 gallons of water was found to be ideal. This spray commends itself from every viewpoint—cheapness, simplicity of preparation, ability to kill quickly, and safety to foliage.

Both homemade and commercial lime-sulphur sprays were carefully tested on cotton, beans, and sweet peas. The mortality on cotton and beans was practically complete, but the results on infested sweet peas were invariably unsatisfactory. With the addition of neither flour paste nor gelatin was this substance effective on sweet-pea foliage. This is quite in agreement with Parker's results, and is explainable through the fact that the pubescent surface of the sweet-pea leaf prevents the even spreading of the insecticide. On cotton, beans, and several other hosts lime-sulphur is a perfect red-spider spray.

Sodium sulphid was tried repeatedly on infested cotton and beans. The greatest mortality obtained against red spiders on beans, a host well adapted to red-spider spraying, was 58 per cent, and the preparation was so strong as to damage the leaves somewhat. The addition of fish glue resulted in a mortality of 95 per cent, but in this case it is believed that much of the destruction was caused by the mechanical action of the glue.

Nicotine Preparations.

Nicotine sulphate and fish-oil soap or miscible oil.—Nicotine sulphate used by itself is very unsatisfactory as a red-spider spray. This preparation was tested at strengths of from 1: 400 to 1: 800 against red spiders on cotton, beans, sweet peas, and violets. The best results were secured on infested cotton, using the extract 1: 640, a mortality of 70 per cent being obtained. When combined with fish-oil soap (one-half ounce nicotine sulphate, one-fourth pound fish-oil soap, 2 gallons water) its effectiveness was perfect.

The mixture of nicotine sulphate (1 to 500) and a miscible oil (1 to 40) also gave complete mortality. The addition of flour paste had almost no noticeable effect in increasing the percentage of mortality. We believe, in the case of the excellent results obtained from the use of combined nicotine sulphate and fish-oil soap, and of combined nicotine sulphate and a miscible oil, that the efficacy was derived principally from the soap and the oil rather than from the nicotine ingredient. The nicotine sulphate applied by itself dries on the foliage in little beads so that the mites in the interstices are not affected.

OILS.

A commercial miscible oil preparation was tested against red spiders on cotton. It was found that a strength of 1 to 20, and even as weak as 1 to 30, sufficed to kill all red spiders, and no injury to foliage resulted. The spray is easily prepared and spreads fairly well over the infested leaves.

An oil that is easily miscible with water is more caustic than the foregoing composition and should not be employed stronger than a dilution of 1 to 32. This miscible oil induced complete mortality to red spiders on cotton, beans, and sweet peas. When one considers the almost invariable failures that have attended the attempts to destroy mites on sweet-pea foliage, an idea of the effectiveness of this preparation may be gained. Its spreading qualities are excellent.

When not less than 2 gallons of kerosene were used to 12 gallons of water in making kerosene emulsion the mortality of mites on cotton and beans was complete. The spreading property of this spray is excellent. The only possible arguments against its employment are the labor of preparation and the slight injury that occasionally occurs to delicate foliage. A weak solution of kerosene emulsion, when fortified with a small amount of a miscible oil, did not give satisfactory results.

ADHESIVE SPRAYS.

In 1903 Volck experimented with flour paste as a spreader for lime-sulphur solution. The success of this additional ingredient, perhaps, may have suggested to Cook and Horne the value of paste alone, for in 1908 they recommended the latter against the red spider. Again, in 1913, Parker determined that a flour paste (cooked), consisting of 1 pound of flour to 1 gallon of water, when diluted at the rate of 1 part paste to 9 parts water, produced complete mortality to red spiders on hops in California. At Batesburg the flour-paste solution, prepared according to Parker's formula, has been carefully tested on sweet peas, violets, beans, hollyhock, and cotton. On sweet peas, violets, and beans the results were unsatisfactory, while on hollyhock and cotton the mortality did not fall below 98 per cent and averaged nearly 100 per cent.

Thinking to utilize only the effective part of the flour, and to simplify the paste-cooking operation, a mucilaginous spray was made by converting laundry starch into paste and diluting it with water. This was applied to heavily infested cotton, and all mites that were hit by the preparation were killed. Since the making of this spray requires less time and care than is the case with flour paste, and since its efficacy appears to be just as good, it would appear thatthis simple mixture should be given further consideration.

Resin Wash.

An insecticide containing, resin 2 pounds, caustic soda one-half pound, fish oil one-fourth pint, and water 10 gallons was given a thorough test on heavily infested beans and cotton. In both cases all red spiders were killed. This preparation possesses the valuable quality of spreading, and is an excellent red-spider spray. The only objection to its general use is the fact that it is not quickly or easily prepared.

Soap Solutions.

A common brand of fish-oil soap, at the rate of one-fourth pound to 2 gallons of water, was applied to mites on beans and cotton. The mortality was complete and the spreading quality of the insecticide was ideal. Other strengths of this solution were tried, and combinations of the fish-oil soap with other substances were tested, but nothing seemed to be added to the efficiency of the soap through these modifications.

In addition to the tests discussed in the foregoing paragraphs, we have conducted several large-scale demonstrations in affected cotton fields. The sprays used in these operations were either potassium sulphid or lime-sulphur, and a barrel pump mounted on some type of horse-drawn vehicle was used for applying the material.

It should be noted that all tests with sprays were conducted during hot, sunny days in the South. This is important to consider in relation to results, since it is becoming known that similar sprays often yield very different results when applied under diverse climatic conditions.

SPRAYING OUTFITS.

The sort of outfit to be used for red-spider spraying[1] depends mainly upon the extent of the occurrence. Many prefer to use a 75-cent tin atomizer when only a score or so of plants are to be treated. This instrument is very economical of liquid and throws a fine, vapory spray which penetrates and blows to all accessible parts, but it is not economical of time, and should be employed only where a quart or two of spray material will complete the job. The bucket pump and knapsack pump (fig. 20, p. 58) come into use in cases of considerable scattered infestation or for treatment of a few plants in tall cotton where the platform pump would be impractical. The most economical outfit for a severe case involving several acres consists of a barrel pump carried through the field on a wagon or on a specially constructed vehicle of some sort. Figure 21, page 59, is from a photograph of a portable outfit devised by a progressive planter at Laurinburg, N. C., from suggestions supplied by the writers. It consists of a platform built upon the axle and shafts of a dismantled hayrake. The two wheels are large, bringing the axle well above the ground, so that injury of the plants is avoided to a great extent. A barrel pump with a capacity of 50 gallons is mounted on the platform. A boy drives, one man pumps, and one handles each sprayer, of which preferably there should be two. Thorough treatment of 3 or 4 acres a day was readily obtained with this device. For safe work the attempt should not be made to use this device in cotton of tall growth, since the passing wagon will injure high plants, but it is ideal in fields of average height or less.

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[1] Our recommendations regarding spraying methods apply primarily to cotton.

Some dissatisfaction has been experienced among certain of those who have undertaken to check the ravages of the red spider by spraying. This can be understood on account of the extreme care which must be exercised in order to secure effective results. From the fact that the mite as a rule passes its entire existence upon the underside of a single leaf, it becomes plainly necessary in spraying to *hit the entire underside of every leaf* of an infested plant. Furthermore, since we have shown that no safe insecticide is known which will destroy red spider eggs, it is clear that a second spraying is necessary to kill the individuals which were eggs at the time of the first spraying.

SUMMARY AND RECOMMENDATIONS.

The common red spider occurs throughout the United States, but is known as a serious pest in only three regions, namely: In that portion of the cotton belt including North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi, where it is primarily a pest of cotton; in north-central and western Colorado as a pest of fruit trees; and in central California, where the species is a rather serious pest of hop fields.

It is estimated that during a season of severe red-spider occurrence the loss to the cotton planters of the Southeast amounts approximately to $2,000,000.

From the records of the present investigation the common red spider is known to maintain itself successfully on 183 species of wild and cultivated plants, weeds, vines, bushes, and trees. A small number of these hosts show special attractiveness for the pest and infestation upon them reaches a more acute degree. These favorite species may be grouped as winter hosts and summer hosts, the former supporting the pest through the cold, inactive period of the year, and the latter furnishing food throughout the spring and summer.

Weeds growing in borders, terraces, etc., and dooryard plants (in the case of fields near dwellings) constitute the sources from which red spiders are able to enter cotton fields. The invasion of fields is accomplished either (1) by travel upon the ground, (2) by travel from leaf to leaf, (3) by the wind, (4) by rain and surface water, or (5) by accidental transportation by farm hands, farm animals, or large insects.

The control of the red spider is possible either by preventive or by repressive measures. Great expenditures of time, labor, and material, however, are necessary when the latter operation is undertaken. Measures of prevention are far more economical and practical.

Clean culture, or the extermination of weeds and plants which breed the pest, is by far the most vital means of prevention that can be applied in the case of field and truck crops.

In cases where cotton is grown within 100 yards of dooryards containing violets and other ornamental plants a careful watch of these plants should be maintained in order that they may be sprayed or destroyed.

By the persistent maintenance of a finely pulverized surface mulch in fields the progress of migrating mites is somewhat retarded and the development of infestation correspondingly discouraged.

Although the fertilization of cotton land in no way interferes with the status of the red spider, and exerts no direct controlling effect on infestation, yet the judicious use of fertilizers assists the plants to overcome injury.

Trap crops, rotation, favorable planting time, irrigation, etc., are either of only slight or of negative value.

Dispersion may be prevented by eliminating the plants in a field which harbor the initial infestation. This may be accomplished by pulling the first few plants which show infestation, or, in case the pest has secured a good foothold, the elimination will be accomplished only by means of plowing up all the affected portion of the field. In either case the stalks should be quickly piled and burned with the help of a little straw or light trash.

Spraying for red spiders is effective if it is done with extreme care. There are a few sprays which will give complete mortality when properly applied, but *a second spraying is necessary to kill the individuals that were eggs at the time of the first spraying.* A contact insecticide is absolutely necessary, and it is vital that every leaf on an infested plant should be reached by the spray.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 417

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

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THE GENUS CALOSOMA:

INCLUDING STUDIES OF SEASONAL HISTORIES, HABITS, AND ECONOMIC IMPORTANCE OF AMERICAN SPECIES NORTH OF MEXICO AND OF SEVERAL INTRODUCED SPECIES.

By A. F. Burgess, *In Charge of Gipsy Moth and Brown-tail Moth Investigations*, and C. W. Collins, *Entomological Assistant.*

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INTRODUCTION.

In 1905 an appropriation was made by the State of Massachusetts for the purpose of bringing to this country parasites and other natural enemies of the gipsy moth and the brown-tail moth. During the same year Congress made a small appropriation to provide for an investigation of the European parasites of these insects and the work was taken up by Dr. L. O. Howard, chief of the Bureau of Entomology. As a result of a cooperative arrangement made between Mr. A. H. Kirkland, then superintendent of moth work for the State of Massachusetts, and the Bureau of Entomology, the general supervision and management of this work was placed in the hands of Dr. Howard and the appropriation by the State was made available for meeting a part of the expense of introducing, breeding, and disseminating such parasites as could be secured. This arrangement was continued after the moth work in Massachusetts was transferred to the State forester and the cost of importations, breeding work, and colonization of parasites from the gipsy moth laboratory, Melrose Highlands, Mass., was jointly financed by the Bureau of Entomology and the office of the State forester, conducted by Mr. F. W. Rane. Owing to the continued spread of the moths above mentioned, and the extension of the infested territory into other New England States, the problem became interstate in scope and since December 1, 1911, the entire work has been financed by the Bureau of Entomology.

A report has already been published by Dr. L. O. Howard and Mr. W. F. Fiske as Bulletin 91 of this bureau,[1] relative to the parasite work, and in Bulletin 101 of this bureau a detailed account is given of the satisfactory results secured from the introduction and establishment, in New England, of *Calosoma sycophanta* L., a predatory beetle imported from several European countries. Bulletin 251 of the United States Department of Agriculture, by A. F. Burgess and C. W. Collins, published in 1915, brings the data known about this predator up to that date.

In connection with the importation of this beetle and of several other species of Calosoma secured from Europe and Japan, it was found necessary to make a thorough study of the seasonal history of the different species concerned, in order that the work might be carried on in an intelligent way. Some time has also been devoted to investigating the seasonal history and habits of some of the native species of this genus, as well as to determining the reason why they have not proved as helpful in destroying lepidopterous larvæ as have the species imported from abroad. Many entomologists and curators of museums throughout the United States and Canada have sent full information concerning the various species of Calosoma in the collections in their charge, together with localities from which the specimens were secured. A considerable number have also forwarded beetles of this genus, and this has made possible an investigation of the habits of a considerable number of species that do not occur in New England. While it is impossible to mention individually all those who have so kindly assisted in this work by furnishing live specimens or data, the writers wish to extend their thanks for the help which has been so freely given. Special acknowledgments are due to Dr. L. O. Howard, who has encouraged the work which has been carried on in this direction and made helpful suggestions from time to time; to Mr. W. F. Fiske for his continued interest and hearty cooperation; to Mr. E. A. Schwarz for examining and determining material received from foreign collectors; to Mr. H. S. Barber and other assistants in the Bureau of Entomology at Washington, D. C., for collecting living material; to Dr. W. D. Hunter and the assistants in Southern Field Crop Insect Investigations of this bureau for similar collections; to Dr. W. M. Mann for the loan of his extensive collection of Calosoma; to Messrs. Kirkland, Rane, and many of the assistants engaged in gipsy moth and brown-tail moth work in Massachusetts, for cooperation and support in carrying on the work which has extended over a period of several years; and to Dr. Henry Skinner, of the Academy of Natural Sciences of Philadelphia, to Mr. Samuel Henshaw, curator of the Museum of Comparative Zoology, at Cambridge, Mass., and to Mr. Charles W. Johnson, curator of the Boston Society of Natural History, for the free consultation of the specimens in the collections of their institutions, as well as for many suggestions relative to the literature on this genus. Among the assistants at the gipsy moth parasite laboratory who have made possible the results which follow by carefully attending to certain phases of the work should be mentioned Messrs. S. S. Crossman, P. H. Timberlake, K. W. Brown, C. W. Stockwell, J. J. Culver, J. V. Schaffner, jr., E. A. Proctor, F. H. Mosher, J. N. Summers, J. E. Dudley, jr., and C. F. Hood. The photographs and illustrations have been prepared by Messrs. W. N. Dovener, H. S. Barber, and H. A. Preston.

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[1] Reprinted as House Document 977, 62d Congress, 3d session.

HISTORY OF THE GENUS CALOSOMA.

The oldest reference to any species of the present genus Calosoma that the writers have been able to trace is that of Réaumur,[1] published in 1736. The legends describing the illustrations merely refer to the species treated as a “scarab,” which was a very general term for beetles at that time. The account of the larvæ feeding in the nests of processionary caterpillars and the admirable illustrations of the larvæ, pupæ, and adults refer to the well-known *Carabus sycophanta* of Linnæus, although without mentioning the specific name of the insect. This reference was later cited by Linnæus [2] and subsequent writers, always in connection with *Carabus sycophanta*. The genus Carabus was described by Linnæus in 1758, or some time previous to that, as it appears in his tenth edition of “Systema Naturæ.[2] In the list of species recorded appear *sycophanta* and *inquisitor* with many others that still remain in that genus. The following description of Carabus is taken from the foregoing publication.

> Carabus. Antennæ setaceae.
> Thorax obcordatus apice truncatus, marginatus.
> Elytra marginata.

Johann A. E. Goeze,[3] in 1777, referred to *sycophanta* as belonging to the genus Buprestis. A. F. de Fourcroy,[4] in 1785, also included this species in the genus Buprestis, giving a short description and notes on its habitat. Johann Guseb Voet [5] writes of *Carabus inquisitor* as *Buprestis sycophanta minor*, and later, in 1799, E. L. Geoffroy [6] includes both *sycophanta* and *inquisitor* in the genus Buprestis. These records are interesting in that they show how these particular two species of Carabus were transferred from their proper place to one of error and confusion. According to the present rules of nomenclature these species rightfully belonged to the genus

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[1] Réaumur. Mémoires pour servir à l'Histoire des Insectes, v. 2, 514 p., 40 pl. (p. 455, pl. 37, fig. 14–19). Paris, 1736.

[2] Linnæus, C. Systema Naturæ, ed. 10, t. 1, 826 p. (p. 413). Leipsic, 1758.

[3] Goeze, J. A. E. Entomologische Beyträge, t. 1, 736 p. (p. 637). Leipsic, 1777.

[4] Fourcroy, A. F. de. Entomologia Parisiensis sive Catalogus Insectorum quae in Agro Parisiensi repe-riuntur. 544 p. (p. 42). Paris, 1785.

[5] Voet, J. G. Beschreibungen und Abbildungen, hartschaaligter Insekten, Coleoptera, Linn., von G. W. F. Panzer, 5 pt., 48 pl. 1793.

[6] Geoffroy, E. L. Histoire Abrégée des Insectes, t. 1, 556 p. (p. 144), 10 pl. Paris, 1799.

Carabus, in which they were included by Linnæus, until Friedrich Weber, in 1801,[1] subdivided the Linnæan genus Carabus into Carabus and Calosoma. The characters of the latter genus are presented verbatim below:

(Calosoma)*

Weberi.

E. Carabis Fabr. Linn.

Labrum breve, late emarginatum, corneum.
Palpi sex.
  Anteriores biarticulati, articulo primo longiore obconico, ultimo cylindrico, adhaerentes maxillae dorso.
  Medii longiores quadriarticulati, articulo primo brevissimo, reliquis obconicis, secundo longissimo, basi anteriorum adnati.
  Posteriores triarticulati, articulo primo brevissimo, secundo longissimo versus apicem paululum incrassato, tertio obconico breviore truncato, ligulae basi inserti.
Mandibula cornea, valida unidentata basi ciliata.
Maxilla cornea basi angulata, processu compresso uncinato, intus basi ciliato.
Labium transversum, corneum, late emarginatum, cum acuminae medio, lateribus rotundatis breviore.
Ligula membranacea, trilaciniata, lacinia media latiore ciliata.
Antennae filiformes, articulo primo valido, secundo brevissimo, tertio longissimo, reliquis obconicis, ultimo cylindrico acuto.
  Character habitualis.
Corpus scutellum, agile latum, alatum, subdepressum, marginatum, colore plerumque nitido.
Caput ovatum, exsertum, magnum, oculis lateralibus prominentibus globosis, antennis lateralibus ante oculos insertis.
Thorax planus, transversus lateribus rotundatis margine prominulo.
Elytra rigida subdeflexa, thorace latiora, longitudine abdominis.
Pedes cursorii, longi, femoribus subcylindricis, tibiis versus apicem paulo incrassatis, ante apicem spinosis, tarsis quinque articulatis.

* "*Sycophanta, inquisitor, alternans, reticulatus*, etc. huc referentur velim. Novem genericum deductum est a pulcher et corpus."

Weber evidently chose *sycophanta* for the type species of the new genus Calosoma either because it was the first species in the Linnæan list of Carabi to possess the foregoing characters or because it was the best known and most common of them. The writers have no good reason nor do they desire to adopt any other as the type for the genus in this paper. *Sycophanta* (Pl. I) has become common in many localities in eastern Massachusetts and southern New Hampshire and is becoming very well known by a large number of the inhabitants of New England and elsewhere. This species is considered the most valuable aid among the Calosomas as a destroyer of tree-feeding larvæ.

GENERAL SEASONAL HISTORY OF SPECIES OF THE GENUS CALOSOMA.

It was found that the various species of Calosoma, both foreign and native, with which experiments were made at the gipsy moth parasite laboratory have rather similar habits. Those which were reared in confinement and are considered in this paper ordinarily entered the earth and deposited their eggs either singly or in groups of from two to three. Propagating adults that are fed in jars containing 4 to 6 inches of earth usually descend to or near the bottom to perform this function. Infertile females which were denied males, frequently deposited large numbers of small eggs on the surface of the earth, seemingly not wishing to leave the surface and lose any possible chance of mating.

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[1] Observationes Entomologicae. Continentes novorum quae condidit generum characteres, p. 20.

The eggs hatch in from 3 to 15 days, depending upon the temperature and season of the year, and to a slight extent upon the species. The longest time is required for those species that deposit many of their eggs late in May and during the first part of June. *C. calidum* Fab. and *C. reticulatum* Fab. emerge from hibernation early in the spring and the number of days spent in the egg stage is greater than with other species, *C. sycophanta* for example, whose normal period of reproduction is from June 10 to July 31. The period in the egg stage is much shorter as the season advances. The eggs of *C. sycophanta* often hatch in three days during very hot July weather.

After hatching, the young larvæ, which are white at first, rapidly grow darker in color. They remain in the location where the eggs were deposited until they reach their permanent color which varies from brown to black, and in from one to three hours begin to move toward the surface of the ground. When confined in jars, if food is not found readily, the more active specimens frequently feed on those that are weaker or less active.

In New England different species of Calosoma larvæ hatch from May 20 to August 15, and feed until mature upon various kinds of lepidopterous larvæ and pupæ. During this period they molt twice, the time in each stage averaging as follows: First stage 3 to 6 days, second stage 4 to 7 days, and third stage 9 to 15 days. When full-grown the larva burrows from 8 to 10 inches into the earth if it is rather soft, and if not, a shorter distance is travelled. From 4 to 7 days are required to prepare a cavity for pupation. The walls are made compact by the movements of the larva within the cell. After the larva has gradually contracted and has become shorter and thicker, the skin is cast and pupation takes place.

The pupa always lies in the cavity resting partly or wholly on the stiff hairs which are present on the dorsal side of the first five abdominal segments. From 10 to 15 days are ordinarily passed in this stage. The pupa is at first creamy-white, but the appendages soon begin to assume the color of the adult insect.

The adult issues during the latter half of July or in the month of August, and some species soon seek the surface of the ground and begin to search for food. *C. calidum* and *C. reticulatum* possess this habit. They feed late in the summer of the year in which they are larvæ and pupæ. Adults of *C. sycophanta*, *C. frigidum* Kirby, and other species remain in the pupal cavity until the following spring before emerging and taking food.

The longevity of the adults of different species apparently does not vary greatly, and under field conditions they undoubtedly survive three years or more. Adults of some of the species may live four years or more, and under conditions where species could be closely observed one female, *C. sycophanta*, has lived for more than four years. The reproduction of the adults in various years has a direct bearing on the age limit. If the beetles reproduce freely during the first and second years of their existence, they usually die at the end of that time.

NUMBER OF GENERATIONS OF CALOSOMA.

Strictly speaking, all the species of this genus thus far reared and studied have only one generation annually. A slight deviation from this rule was noted in the case of 2 males and 4 females of *C. scrutator* Fab. that were received from Onset, Mass., August 3, 1909. These beetles were placed in a Riley cage and given plenty of food at frequent intervals. On September 23 and 27, 23 small larvæ hatched from eggs deposited by one or more of the females. They were isolated and later fed inside the laboratory. Adults developed from some of these larvæ, November 9 to 12, and a few days later (November 16 and 19) were found on the earth in the jar searching for food. They fed until December 16, before entering hibernation.

This instance is cited to show that reproduction may take place in some cases very late in the season. Other females of the same species, confined at the laboratory that year, began ovipositing as early as June 14, which gave ample time for adults to develop before the middle of August. It is doubtful whether the adults of *C. scrutator* under field conditions in New England come to the surface of the earth for food as soon as they issue. The instance just cited indicates that they may do this in the southern United States.

FOOD HABITS OF ADULTS AND LARVÆ OF CALOSOMA.

The kind of food consumed by the adults and larvæ of the various species varies greatly under natural conditions. Of all the species with which experiments were made at the laboratory, everything offered in the way of lepidopterous larvæ and pupæ was eaten, and in some cases immature stages of Coleoptera and Diptera were attacked sparingly.

The caterpillars of *Porthetria dispar* L. and *Malacosoma americana* Fab. were fed more than other species because of their abundance in the field at the time needed (Pl. II, A). Caterpillars of *Euproctis chrysorrhœa* were abundant enough, even more so in some localities than the former species, but the ubiquitous and poisonous hairs of the caterpillars of the latter made their general use impracticable.

The beetles are ravenous for food at the time when the caterpillars of the foregoing species are in season and their larvæ feed voraciously upon either caterpillars or pupæ but usually destroy more of the latter. This is particularly true of the larvæ of *Calosoma sycophanta* in connection with *Porthetria dispar.* Many field observations have shown that the larvæ of the beetles are abundant at the precise time when caterpillars of this species are entering the pupal stage, and as much food is required for their development they are particularly adapted for destroyers of this pest. The same is true with the larvæ of *C. frigidum* in their feeding upon larvæ and pupæ of *Heterocampa guttivitta* Walk. These observations were published by Mr. W. F. Fiske[1] and the senior writer in 1910. On July 31 of that year Messrs. Fiske and Burgess found the adults of the beetle climbing trees and preying upon the caterpillars of the moth in Tamworth, N. H. On the same date 12 of the beetle larvæ were found in 1 square yard of leaf mold feeding upon the caterpillars that were congregating there for pupation. Further observations were made on August 21, which showed that as many as 80.2 per cent of the pupæ of *H. guttivitta* in one locality had been destroyed in the leaf mold by the larvæ of this beetle.

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[1] Fiske, W. F., and Burgess, A. F. The natural control of *Heterocampa guttivitta*. *In* Jour. Econ. Ent., v. 3, no. 5, p. 389-394, 1910.

Burgess, A. F. Notes on *Calosoma frigidum* Kirby, a native beneficial insect. *In* Jour. Econ. Ent., v. 3, no. 2, p. 217-222, 1910.

Both adults and larvæ of *C. calidum* Fab. search for their food on and near the ground. The species of cutworms which are often abundant during the spring and early summer furnish ideal food for this predacious insect and large numbers are destroyed annually.

Dr. A. W. Morrill has found that *C. peregrinator* Guér. in both the adult and larval stages is common as an enemy of the variegated cutworm (*Peridroma margaritosa* Haw.) in Arizona, and the late H. M. Russell of this bureau reported finding adults of *C. semilaeve* Lec. at Hollywood, Cal., April 7 and 27, 1911, feeding upon the larvæ of *Peridroma margaritosa* under pea vines. This indicates that the food habits of these two species of Calosoma are very similar to those of *C. calidum* in both the adult and larval stages.

Other data have been collected by various entomologists, and many observations were made at the laboratory at Melrose Highlands, Mass., most of which are given under the notes on each species and indicate that great benefit must result from the work of these inconspicuous friends.

ECONOMIC IMPORTANCE OF THE SPECIES OF CALOSOMA.

The economic importance of *Calosoma sycophanta* has been set forth in Bulletin 101 of the Bureau of Entomology by the senior author [1] and more recently by both authors [2] in Department Bulletin 251, but since the former publication was issued other interesting notes have accumulated and may well be added here. Dr. J. N. Summers of this bureau, during the early spring of 1912, began a careful study of the internal parasites of the brown-tail moth larvæ in a 4-acre sprout lot in South Lynnfield, Mass. In June it became necessary to discontinue the observations owing to the depletion by *C. sycophanta* of the larvæ and pupæ of the brown-tail moth. The Calosoma beetles had consumed in some cases from 50 to 75 per cent of the brown-tail moth pupæ per tree or, as was figured later, an average of 40 per cent for the whole area.

Mr. W. F. Fiske, recently of the Bureau of Entomology, while studying the gipsy moth and its parasites in Italy during the summer of 1911, was afforded an opportunity of observing the efficient control of the gipsy moth by *C. sycophanta* in a large forest. Mr. Fiske states that there were enough beetles in the forest at the time of his visit to consume all the gipsy-moth pupæ present, with the exception of those hanging from the trunks of trees or limbs which could not be reached by the predators.

The beneficial work which is being done by this species of Calosoma in New England through its feeding upon the gipsy moth and the brown-tail moth is now common knowledge in the section that has been longest infested by these pests.

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[1] Burgess, A. F. Calosoma sycophanta. U. S. Dept. Agr. Bur. Ent. Bul. 101, 94 p. (p. 48), 9 pl., 22 fig. 1911.

[2] Burgess, A. F., and Collins, C. W. The Calosoma Beetle (*Calosoma sycophanta*) in New England. U. S. Dept. Agr. Bul. 251, 40 p., 7 pl., 3 fig. 1915.

An outbreak of *Heterocampa guttivitta* in the White Mountain district of New Hampshire and parts of Maine began to attract attention in 1906 and 1907. The moths increased rapidly for several years and large areas of hardwood growth on the mountain sides were completely stripped. In 1909 this destruction reached its climax. *Calosoma frigidum* had by this year increased to such proportions that its effective work was everywhere evident in localities where these caterpillars had made their appearance. The junior writer had an opportunity of visiting several localities in North Conway, Intervale, and Tamworth, N. H., on August 20, 1910, when conditions were almost entirely relieved in so far as the ravages of the caterpillars upon the foliage were concerned. Examinations were made of many small areas of leaf mold where the moths had pupated in August, 1909, and it was found that an average of 87 per cent of the pupæ had been destroyed by the larvæ of *C. frigidum*, and that 3.7 per cent had died from the attack of parasites or from other causes. The remaining 9.3 per cent emerged during the spring of 1910, and the females deposited eggs that were immediately attacked by a small egg parasite, *Telenomus graptæ* How., which destroyed practically all of them. This shows the good work of *C. frigidum* coupled with the timely aid of parasites.[1]

A similar example of effective control to that of *C. frigidum* on *Heterocampa guttivitta* in New Hampshire was noted by Dr. J. B. Smith [2] in southern New Jersey a few years ago. This had to do with an outbreak of a geometrid caterpillar which covered the scrub oaks in enormous numbers. *Calosoma scrutator* and *C. wilcoxi* Lec. were also there in enormous numbers on the young oaks, feeding upon the geometrid caterpillars. Dr. Smith visited the locality the year following the outbreak but could not find a single specimen of beetles or caterpillars. This is an instance in which the beetles came in and made an entire clean-up of the lepidopterous pest, after which they evidently migrated to other sections and in all probability many died of starvation.

Calosoma calidum is quite common in localities where cutworms are doing great damage to crops. It is sometimes difficult to find adults of this species or their larvæ actually preying upon the worms, but the evidence of their presence in such an environment usually bespeaks their mission. Besides, as stated before, it is believed that *C. calidum* is more or less nocturnal in its food habits, which is much in its favor as an efficient enemy of cutworms. Numerous other accounts are on record concerning the beneficial work of the various species of Calosoma, although the previous records of some of the species are rather fragmentary.

LIMITS ON INCREASE OF SPECIES OF CALOSOMA.

Probably the most potent factor to be reckoned with when considering the increase of any species of Calosoma is the possible food supply. Second to this is the feeding and pupation habits of its lepidopterous host, for it is necessary that the caterpillars be feeding and pupating at the time when the adult beetles will reproduce.

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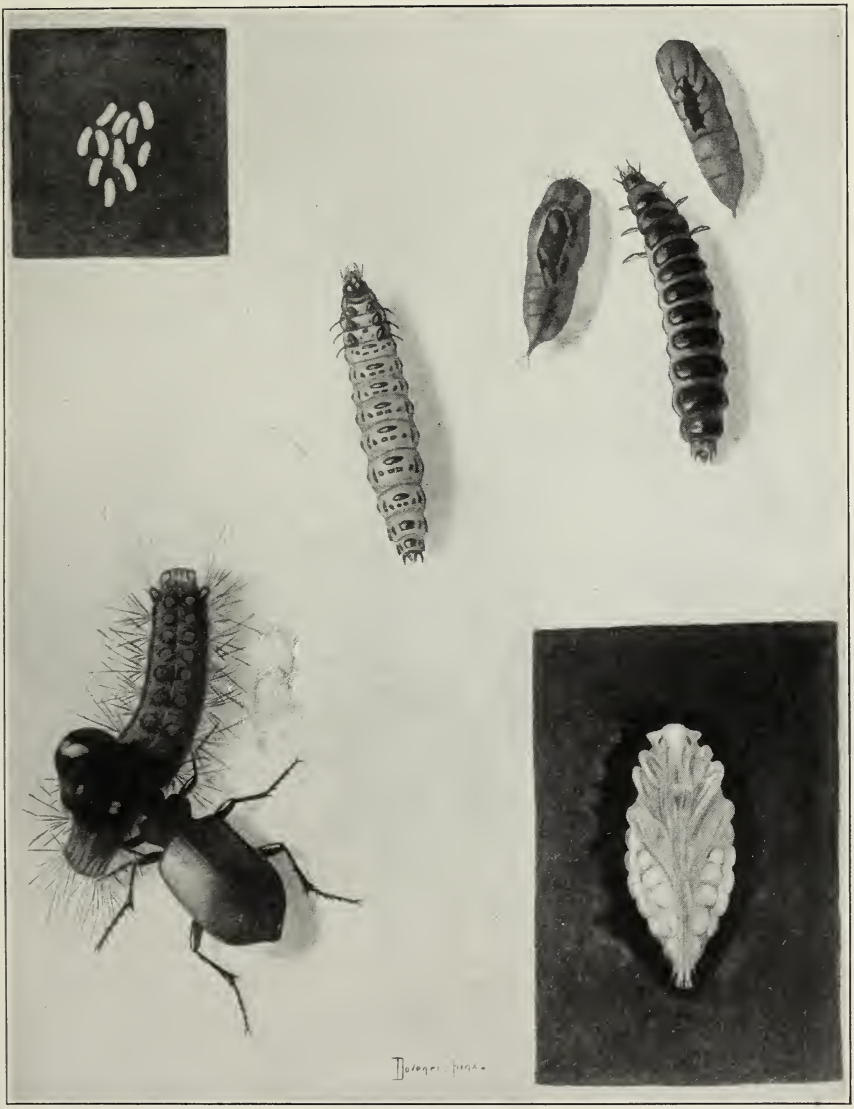
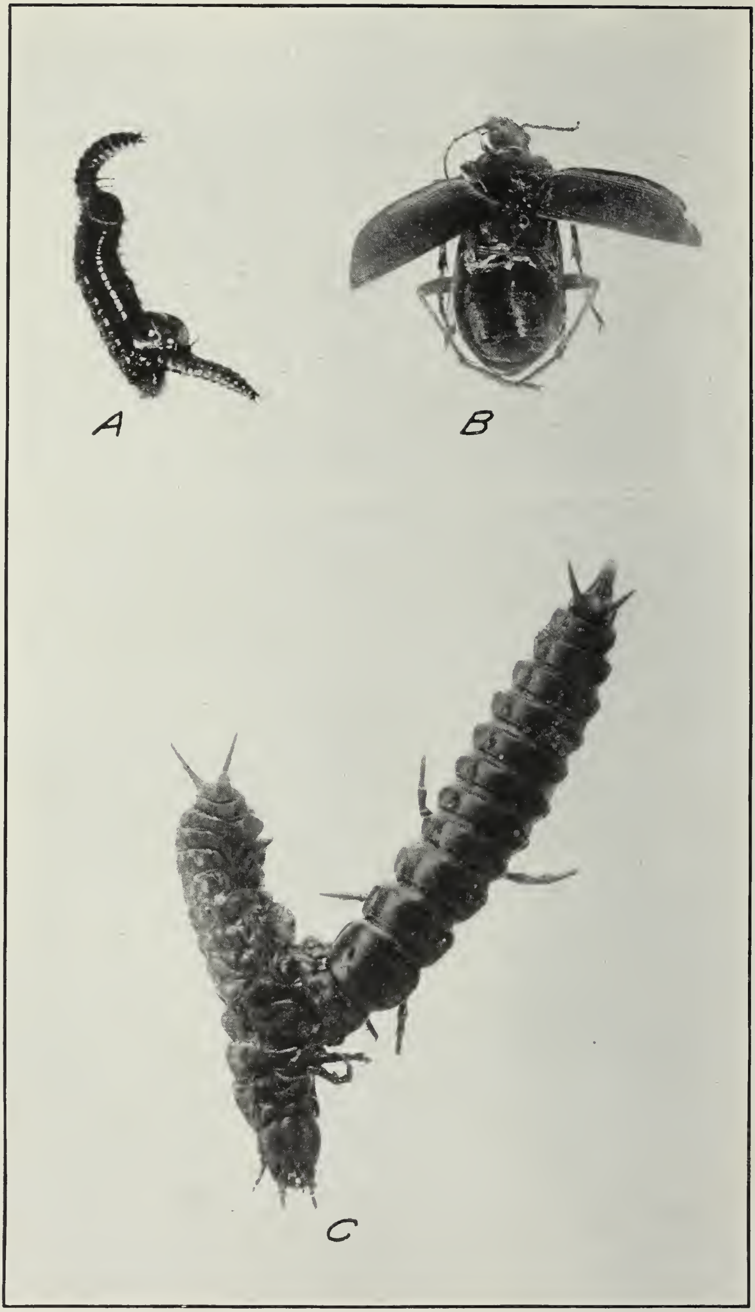
[1] The notes with others were published by Messrs. Burgess and Fiske in the Journal of Economic Entomology, Volume 3, Number 5, page 389, 1910.

[2] Smith, J. B. [Note.] *In* Ann. Ent. Soc. Amer., v. 4, p. 179, 1911.



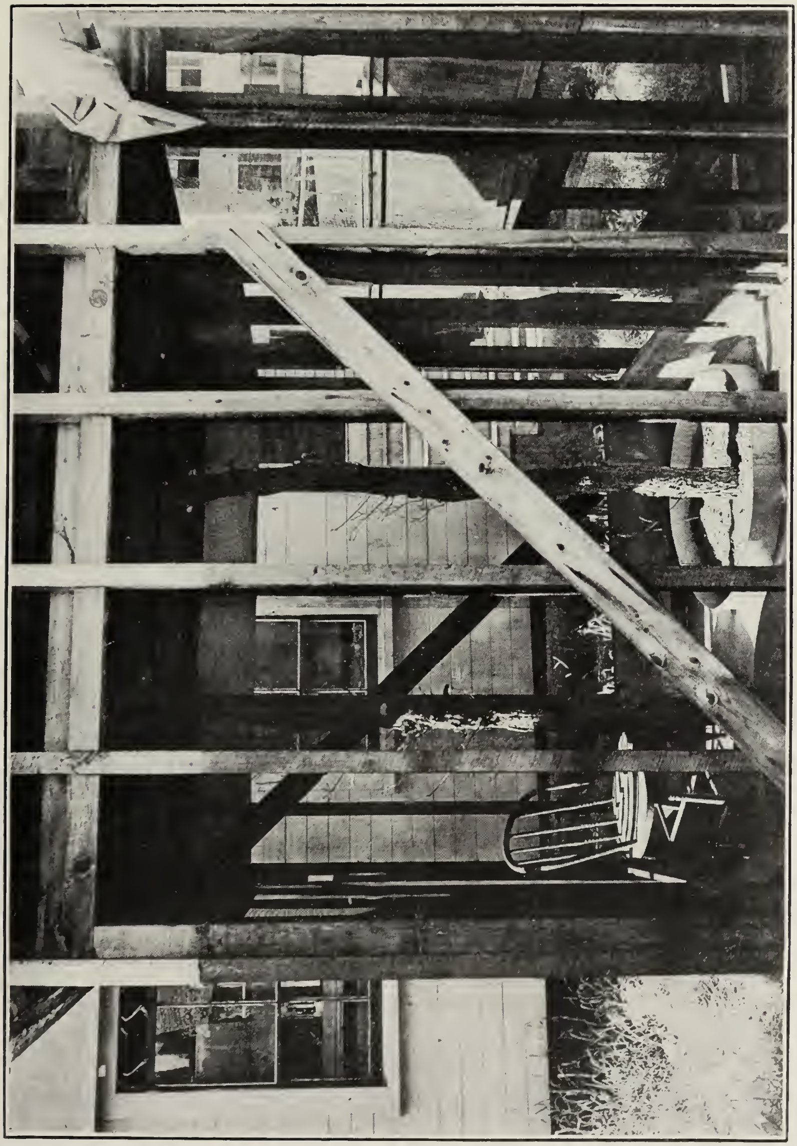
CALOSOMA SYCOPHANTA.

Adult Calosoma beetle eating gipsy moth caterpillar, lower left; pupa, lower right; eggs, upper left; eaten pupæ of gipsy moth, upper right; full-grown larvæ from above and below. All slightly reduced. (Howard and Fiske.)



CALOSOMA LARVÆ FEEDING, AND PARASITIZED BEETLE.

A.—First-stage larvæ of *Calosoma sycophanta* feeding on larva of the American tent caterpillar (*Malacosoma americana*). *B.*—*Calosoma sycophanta*, showing puparia of parasitic fly *Biomyia georgiae* beneath wing covers. (Slightly enlarged.) *C.*—Larva of *Calosoma frigidum* feeding on another larva of the same species. (Original.)



TREE-CLIMBING HABITS OF CALOSOMA LARVÆ AND BEETLES.

Outdoor shelter containing apparatus used in testing the climbing habits of Calosoma beetles and their larvæ. (Original.)

THE SKUNK AN ENEMY OF THE CALOSOMA BEETLES.

Excrement of skunk collected in the field showing many fragments of adults of *Calosoma sycophanta*. (Authors' illustration.)

For instance, if caterpillars and pupæ of *Malacosoma americana* and *Euproctis chrysorrhœa* were the only source of food for *C. sycophanta* in New England it is very probable that the beetles would increase very slowly if at all. The adults of Calosoma emerged from hibernation at Melrose Highlands, Mass., in 1910, between May 11 and June 28, the average date being June 2.[1] Usually a week or more intervenes before active egg deposition begins, and it is about June 15 before the eggs begin to hatch. The Calosoma larvæ that hatch from the first eggs deposited usually find ample food in the caterpillars and pupæ of *M. americana*, large, full-fed caterpillars of *E. chrysorrhœa*, and a little later the pupæ of this species. The supply of Malacosoma for food purposes is practically exhausted by June 25, and that of Euproctis by July 15. Between these dates the most active reproduction of *C. sycophanta* takes place under present conditions, and it is evident that the bulk of the larvæ would die from starvation if other food were not available. On the other hand, the habits of this beetle and its larvæ are so well adapted to those of the gipsy moth that it seems impossible for any other species of Calosoma to fare better on this particular prey.

Cannibalism among the larvæ of the various species is also no small factor in limiting the increase. All the species reared at the laboratory and further treated in this paper possess this habit in the larval stage. Irreparable losses have resulted in laboratory experiments when attempts were made to feed from 8 to 15 larvæ in a battery jar with 2 to 3 inches of moist earth in the bottom. As soon as the food supply was nearly exhausted the larvæ began to attack one another. (Pl. II, *C.*) Despite the large number of *sycophanta* larvæ reared for colonization work in New England, it was impracticable to feed many of them together for more than from four to six days after hatching, as the mortality in captivity became too high. After these larvæ reached the second stage the mortality rapidly increased from this cause. Cannibalism does not appear to be of special importance under field conditions unless the food supply is greatly restricted.

The ability of Calosoma larvæ to climb into the trees is an important factor. Many species are unable to do this and it is therefore impossible for them to feed upon arboreal lepidopterous larvæ. Species of Calosoma larvæ that are able to climb are thereby enabled to increase more rapidly and are of greater economic importance except in cases where the habits of the host are strictly terrestrial.

EXPERIMENT TO DETERMINE THE CLIMBING HABITS OF CALOSOMA LARVÆ.

A small white oak tree was cut during the spring of 1911 and two sections of it, each 6 feet 5 inches long and about 3½ inches in diameter, were set upright in a cage at the laboratory so that a study might be made of the climbing habits of the various species of Calosoma. The sections of the tree were held in place by wires attached near the top, and the base, which rested on the cement floor of the cage, was encircled by a strip of tin 4 inches high. This inclosure,

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[1] Burgess, A. F. Calosoma sycophanta. U. S. Dept. Agr. Bur. Ent. Bul. 101, 94 p. (p. 48), 9 pl., 22 fig. 1911.

3½ feet in diameter, prevented the larvæ from making their escape. A small amount of earth was placed in the circle. Later the size of the circle was reduced to 21 inches in diameter and it was found necessary to attach several partitions to the strip of tin, which extended nearly to the tree, in order to prevent the larvæ from traveling around the outer part of the inclosure (Pl. III).

A food cage, the bottom of which was made of ¼-inch mesh cellar-window screen and the sides and top of fly screen, was perched on the flat top of each section of the tree. The cage was made just large enough so that the bottom projected about one-half inch beyond the bark of the tree on all sides and the Calosoma larvæ had no difficulty in entering it if they were good climbers. *P. dispar* caterpillars or pupæ or both were placed in these cages, and the presence of the beetle larvæ could be easily determined by the injured specimens in the cages.

Tests were made with the larvæ of 11 species of Calosoma, namely: *Sycophanta* L., *scrutator* Fab., *calidum* Fab., *frigidum* Kirby, *lugubre* Lec., *externum* Say, *inquisitor* L., *reticulatum* Fab., *chinense* Kirby, *semilaeve* Lec., and *cancellatum* Esch. When possible the larvæ in each stage were used.

The results secured demonstrate that *sycophanta* is a natural climber in all larval stages; *reticulatum* larvæ climb considerably and with apparent ease; *chinense* climbs to some extent, but not so much as the preceding species. Larvæ of *scrutator* and *lugubre* are in about the same class, and seem able to climb to a small extent, but are very rarely inclined to do so. The larvæ of the remaining 6 species, *calidum*, *frigidum*, *externum*, *inquisitor*, *semilaeve*, and *cancellatum* show very little ability and no inclination to ascend trees.

Considerable information has been secured on the climbing habits of several species of adults and this is given under the species concerned.

NATURAL ENEMIES OF CALOSOMA.

It is undoubtedly true that beetles of this genus are destroyed in more or less numbers each year by natural enemies. The principal vertebrate enemies concerned are the toad, skunk, and various species of insectivorous birds. A considerable number become the prey of parasitic and predacious insects, although only a small amount of data is at hand to prove this assertion. Several cases are on record where adults of *C. calidum* have been found among the remains taken from the stomachs of toads, and Mr. F. H. Mosher, of the Bureau of Entomology, has observed these animals feeding on the species in the field. This observation was confirmed by an examination of the excrement, which contained small particles of the chitinous remains of this species.

On July 9, 1912, Mr. J. E. Dudley, jr., of the Bureau of Entomology, collected in Stoneham, Mass., a considerable amount of toad excrement in which parts of *C. calidum* could readily be determined.

During the summer of 1912 numerous observers reported that skunks were undoubtedly feeding upon specimens of *Calosoma sycophanta*. Most of these reports came from sections where this beetle was abundant and there seemed but little doubt as to the accuracy of the reports, although definite data were lacking. In order to secure more information on this subject a series of experiments was conducted by the junior author using captive skunks, foxes, and raccoons. The results of these experiments are given in a following paragraph and indicate that the skunk will feed freely upon these insects. Field observations in 1913 have confirmed the experimental results referred to above. In many sections of the territory infested by the gipsy moth where *C. sycophanta* has become abundant, unquestionable evidence was secured that skunks were destroying them in large numbers. In some cases it was possible to find the ground thoroughly uprooted over considerable areas, which indicated that these animals had been digging to secure beetles which were beneath the surface of the ground. In addition to this, large amounts of excrement were obtained, which showed that these beetles formed a large percentage of the food of the skunk. (Pl. IV.) In some cases it would appear that the work of this animal during the past year has been sufficient to retard seriously the increase of this beneficial species.

In June, 1912, a series of observations were made by Mr. Mosher in woodland near Melrose to determine whether birds were feeding upon Calosoma beetles. For some time previous it had been noted that along paths and wood roads a considerable number of wing-covers and parts of beetles were frequently seen. Although Mr. Mosher did not actually see birds feeding upon the beetles, he did observe many specimens of the towhee or chewink (*Pipilo erytrophthalmus*) in the woodland and saw one devouring a female specimen of *Prionus laticollis.* In the attempt to consume this insect the elytra were separated from the thorax and the eggs and internal tissues were eaten. As most of the hard parts of the insect were rejected, it is fair to assume that this bird may have attacked Calosoma beetles in the same manner.

The brown thrasher (*Toxostoma rufum*) has a somewhat similar feeding habit and may be considered a possible enemy of these beetles.

During the summer of 1913 observations were made by Mr. J. V. Schaffner, jr., and Mr. A. M. Wilcox, of the Bureau of Entomology, which indicate that the crow is an enemy of Calosoma adults. One of these birds was observed to seize a beetle and to convey it to its nest in a near-by tree. Several parts of beetles were found at the base of this tree and on examining the nest, which was occupied by young crows about 3 weeks old, five broken and torn beetles were found.

Among the insect enemies of Calosoma are the predacious bugs, although only a few records are available to support this conclusion. On July 7, 1910, Mr. Schaffner observed a nymph of *Podisus* sp. feeding upon a second-stage larva of *Calosoma sycophanta* at Brookline, Mass. During each season several different species of Podisus are found in Massachusetts, although they are not ordinarily abundant enough to destroy many insects.

In 1896 Mr. Burgess reared several tachinid flies from an adult of *Calosoma calidum.* These were determined by the late D. W. Coquillett as *Pseudatractocera calosomae* Coq., a species which he had reared some years previous from *C. peregrinator* Guér. in California. Since that time this species has been classified under the name *Biomyia georgiae* B. & B.

In 1912 several tachinid flies (Pl. II, *B*) were reared by the junior author from *C. sycophanta*, but the adults which emerged were so badly crippled that determination of the species was very difficult. The specimens have been examined by Mr. Frederick Knab, of the Bureau of Entomology, and also by Mr. Charles W. Johnson, of the Boston Society of Natural History. Their determinations agree that the species is either *Biomyia cinerea* Fall. or *B. georgiae*. Unfortunately there are no pinned specimens of *cinerea* with which the material reared could be compared, but owing to their poor condition and to the fact that these tachinids were reared from a Calosoma beetle collected in Massachusetts and not from one imported directly from Europe, it is probable that the species concerned is *georgiae*. Tachinid puparia have been found in the bodies of both *C. calidum* and *C. frigidum* during the last few years, and a careful comparison has failed to indicate any differences between these and the puparia of *georgiae*. Unfortunately, adults were not secured from these puparia. Mr. Johnson believes that this species should be more correctly referred to the genus *Viviania* Rond., so that rather positive evidence is at hand that *Viviania georgiae*[1] attacks three species of Calosoma in this country, namely, *calidum*, *frigidum*, and *sycophanta*. It is probable that the percentage of parasitism of Calosoma beetles by this tachinid is rather small, as only a few records of its work have been secured.

EXPERIMENT TO DETERMINE IF SKUNKS, FOXES, AND RACCOONS PREY UPON CALOSOMA BEETLES.

January 27, 1913, the junior writer took some living adults of *sycophanta* to Franklin Park Zoological Garden, Boston, Mass., and secured permission from Mr. J. T. Benson, curator, to isolate one skunk (which happened to be an old female), and these specimens were offered as food. The animal was placed in the cage about 10.30 a. m. and a cigar box one-half full of earth, containing four adult beetles, was put in at the same time. She scarcely noticed the box of earth at first, but by 12 m. had tipped it over and consumed the four beetles, leaving only two elytra. Two extra specimens were put in the cage at noon and these were quickly consumed. Excrement was passed in the afternoon of that day, but no parts of the beetles were found in it. The following morning excrement was removed from the cage. It was composed partly of undigested parts of *sycophanta*, including elytra, legs, and other chitinous appendages. (Pl. IV.)

The same sort of an experiment was conducted with a red fox (*Vulpes fulva*) and a raccoon (*Procyon lotor*), on January 25, 1913, at the Middlesex Fells menagerie, Stoneham, Mass. Mr. A. N. Habberley, superintendent of the Fells division, Metropolitan Park System, kindly permitted these animals to be used for the purpose. A cigar box of earth containing three males and one female *sycophanta* was placed in the cage at 9 a. m., but the fox would not notice them until Mr. Habberley and the junior writer had receded a short distance from it. In less than 10 minutes from the time they were put in the animal tipped over the box and consumed all the beetles. Later a fresh dead female was thrown into the cage and was eaten immediately. Excrement was found in the cage on the morning of January 27 which contained well-ground particles of the beetles.

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[1] Specimens have been described recently by Dr. C. H. T. Townsend as *Eubiomyia calosomae* coq.

The raccoon when offered adult *sycophanta* ate from the hand three males and two females in rapid succession. The beetles were ground up in coarse particles and were found in the excrement on the morning of January 27. The appearance of the remains in the excrement very much resembled those in the excrement of the skunk.

Even though the foregoing experiments were conducted under unnatural conditions, there is little doubt that these animals destroy *sycophanta* and other species of Calosoma in woodland where the beetles are plentiful. The skunk is the most important of these animals as a natural enemy of Calosoma in New England, as it is common in some sections, while the fox and raccoon are comparatively rare. In other sections of the United States the latter animals may prey upon Calosoma rather extensively.

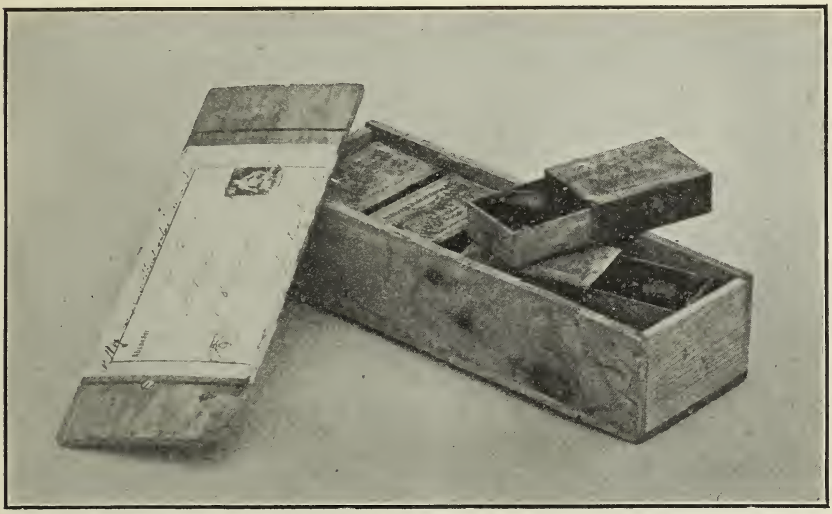

FIG. 1.—Boxes for shipping Calosoma beetles. Each match box contains a single beetle and a small quantity of wet sphagnum moss. (Burgess.)

METHODS OF SHIPPING CALOSOMA BEETLES.

During the past few years several thousand specimens of Calosoma beetles have been received and shipped. When live adults are to be forwarded and will not be in transit more than one day, they can be placed in a wooden box with a small amount of twigs and foliage and sent by express or mail. It is usually desirable to bore a few holes in the sides of the box and cover them with wire netting, but it is not necessary to add food for the beetles as they will survive the journey well unless the temperature is excessive.

When the length of time in transit is a week or longer, each beetle should be placed in a small box (a safety-match box is excellent for this purpose), with a small amount of wet sphagnum moss (fig. 1). No food need be added, but the packing should be such as to furnish some moisture for the beetles until the end of the journey.

In the writers' experience more specimens have died from lack of moisture than from any other cause. Metal containers are not desirable because too much moisture is present. The small boxes mentioned can be placed in a larger box and shipped by mail or express.

In case two or three weeks will be required for the journey it is desirable to ship in cold storage if the beetles are collected early in the season. Several lots have come from Japan that were shipped in this way during midsummer and they always arrived in good condition when the packing material did not become too dry.

METHODS OF REARING CALOSOMA BEETLES.

[Pl. V.]

Calosoma beetles are not easily reared, and as a rule considerable experience is necessary in order to manage the early stages successfully and obtain perfect adult specimens. All the species which have been under observation deposited their eggs in the ground and both male and female beetles usually spent a part of the time in the ground or under litter. When definite records are desired as to the number of eggs deposited by females or the molting periods of the larvæ, it has been found desirable to use glass battery jars containing from 2 to 4 inches of loam. A pair of beetles are placed in each jar and caterpillars added for food. A wooden cover provided with a groove which fits the top of the jar (fig. 2) has been found more satisfactory than covers made of cheesecloth or other material. A circular hole is made in the top of each cover and a piece of wire screen is tacked over it so as to afford free circulation of air and prevent the escape of the beetles. It has been found advantageous to attach narrow strips of wire netting to the top of the cover in such a manner that they extend nearly to the surface of the earth in the jar. The beetles are not able to climb the vertical sides of the jar, and as the caterpillars can do so easily the netting serves as a

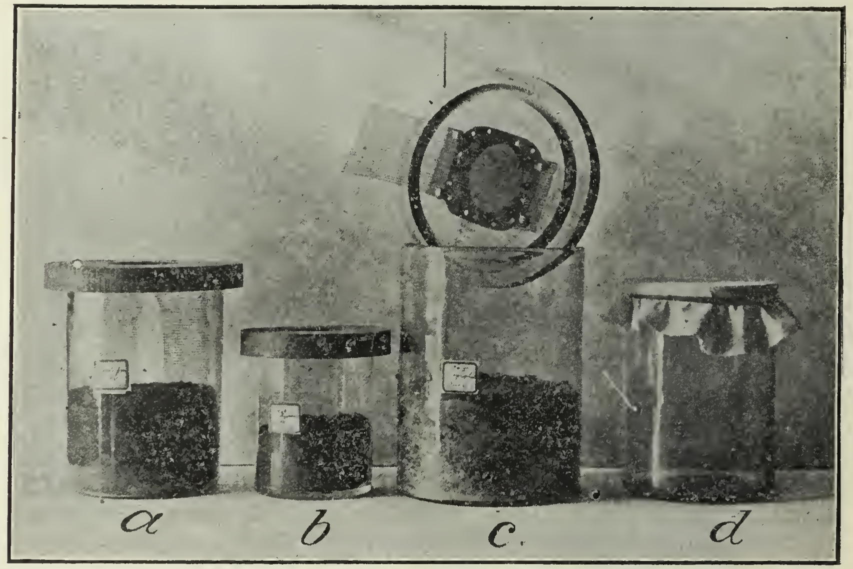

FIG. 2.—Jars for rearing Calosoma beetles: *a*, Large jar with wooden top and "ladder"; *b*, small jar with wooden top; *c*, showing construction of top and "ladder"; *d*, jar with cheesecloth top held in position with rubber band. (Burgess.)

ladder and permits the beetles to reach the top of the jar and feed upon any of the caterpillars that may crawl to this location. A small amount of foliage to serve as food for the caterpillars should be placed in the jar, and it should be cleaned daily and all dead specimens removed. This is necessary in order to prevent the development of certain species of mites that feed on caterpillar remains and in turn attack and sometimes kill the breeding beetles or larvæ. The earth should be examined from time to time to determine whether eggs have been deposited, and when they are found the beetles should be transferred to a fresh jar and the eggs allowed to remain undisturbed for hatching. As soon as larvæ appear they should be removed and placed in other jars containing earth. Ten larvæ of most species of Calosoma can be reared through the first stage in a jar of earth 6 inches in diameter, but if it is desired to carry the larvæ through to the adult stage each specimen should be placed in an individual jar, as they show a decided tendency to attack one another, especially at the time of molting. The size of the jars should be determined according to the size of the species which is to be studied, but in the writers' experience none of the species can be satisfactorily handled in jars less than 4 inches in diameter. In case definite records are not desired or if time is not available to care for a large number of individual jars, rearing can be carried on by using large cages, the bottoms of which are filled with earth (fig. 3). In all cases it is necesasary to keep the earth moist, but not wet. If too much water is added, the legs and mouthparts of the beetles and larvæ become coated with earth and the insects soon die. When the larvæ are fed in jars and it is desired to secure adult specimens, one of the most satisfactory methods is to construct small cylinders of

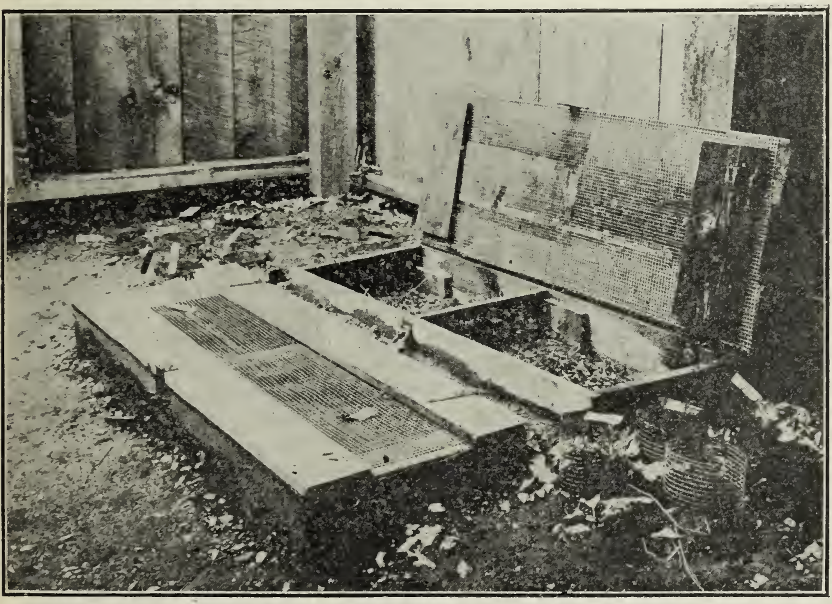

FIG. 3.—Box cages for hibernation of Calosoma beetles. (Burgess.)

mosquito wire netting about 4 inches in diameter. These should be sunk in the ground from 10 to 12 inches and the top should be closed with a wooden plug. The large larvæ can be placed in these cages, and if supplied with food will remain there and burrow into the ground when ready to pupate. Care should be taken to have the earth in these cages firm, but not too compact. In cases where it is loose the larvæ will not be able to form a satisfactory cavity in which to pupate and the insect will die before emerging as an adult. Many of the details in rearing Calosoma beetles must be learned from experience, but the general directions given above will serve to aid anyone desiring to carry on this interesting work.

CLASSIFICATION OF CALOSOMA.

The following table has been prepared for the separation of the species of Calosoma occurring in the United States. It consists simply of a revision of a similar table published by LeConte[1] in 1878, with a few changes and additions to include *sycophanta* L., *inquisitor* L., *reticulatum* Fab., and *auropunctatum* Payk., imported from Europe, and *chinense* Kirby and *maximowiczi* Mor., secured from Japan. All of these species have been liberated in New England except *auropunctatum* Payk. and *maximowiczi* Mor. The former species has been studied at the laboratory, but not enough specimens were received for liberation. Only two females of the latter species were received from Japan, and as the classification is based on the characters of the male this species is added at the end of the table.

C. carbonatum Lec. is considered a synonym of *C. peregrinator* Guér.; *morrisonii* Horn, *prominens* Lec., *parviceps* Casey, and *tristoides* Fall have been added to those treated by LeConte, as they are apparently good species, the writers having had an opportunity to study specimens. A male of the last species was presented to the junior writer by Mr. H. W. Wenzel, of Philadelphia, as coming from the Ricksecker collection. One specimen of *C. dietzii* Schäf.[2] was also seen in Mr. Wenzel's collection and is evidently a good species, but could not be included in the table as the description does not give the characters of the male tarsi.

Col. Thos. L. Casey,[3] [4] in 1897, described the following species of Calosoma: *Sponsa*, *marginalis*, *parviceps*, *monticola*, and *arcuata*. In some cases these species were described from one or a very few specimens, and the types are held in his private collection. No other specimens of these species have been secured for study except *C. parviceps*. Some unidentified examples of this species were found in the collection at the U. S. National Museum. It has, therefore, been placed in the following table, but it has not been thought best to include the others on account of the small amount of material available.

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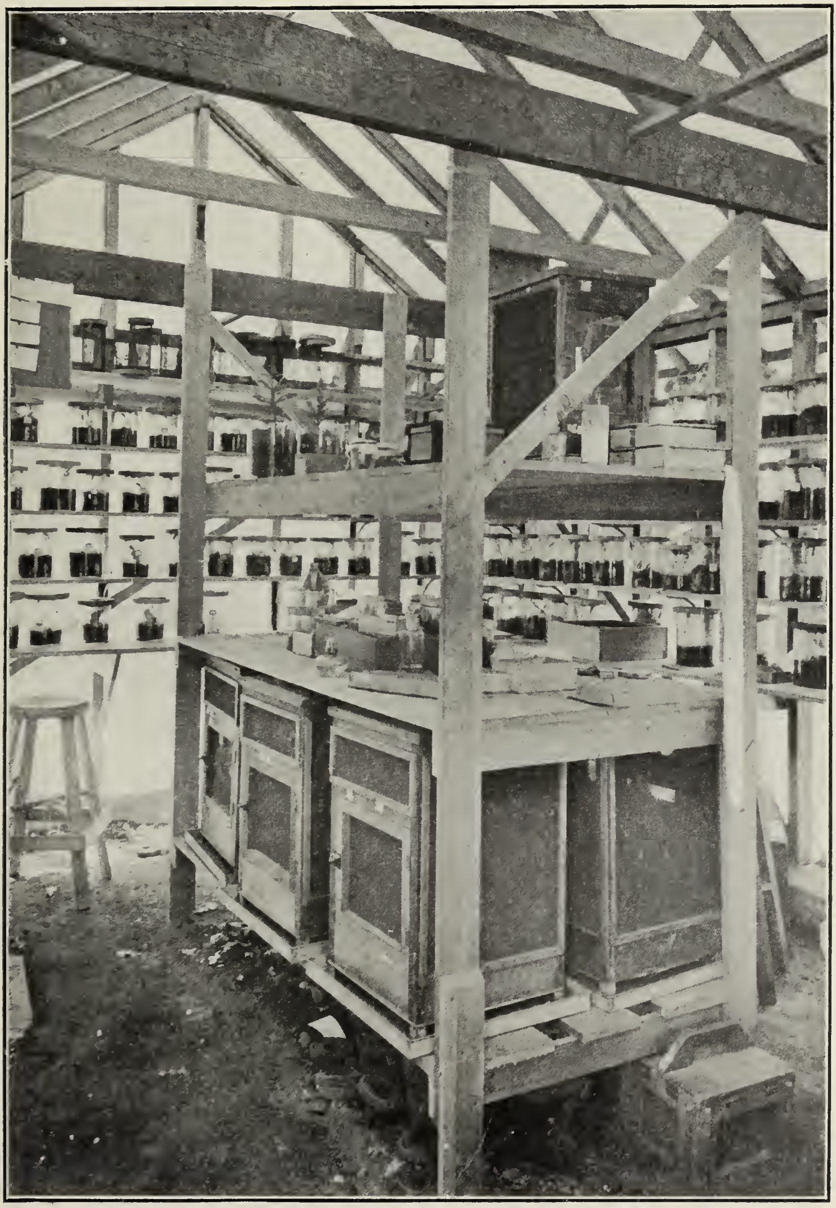
[1] LeConte, J. L. Description of a new species of Calosoma. *In* Bull. Brooklyn Ent. Soc., v. 1, no. 8, pp. 61–66, 1878.

[2] Schäeffer, Charles. New genera and species of Coleoptera. *In* Jour. N. Y. Ent. Soc., v. 12, no. 4, pp. 197–236, 1904.

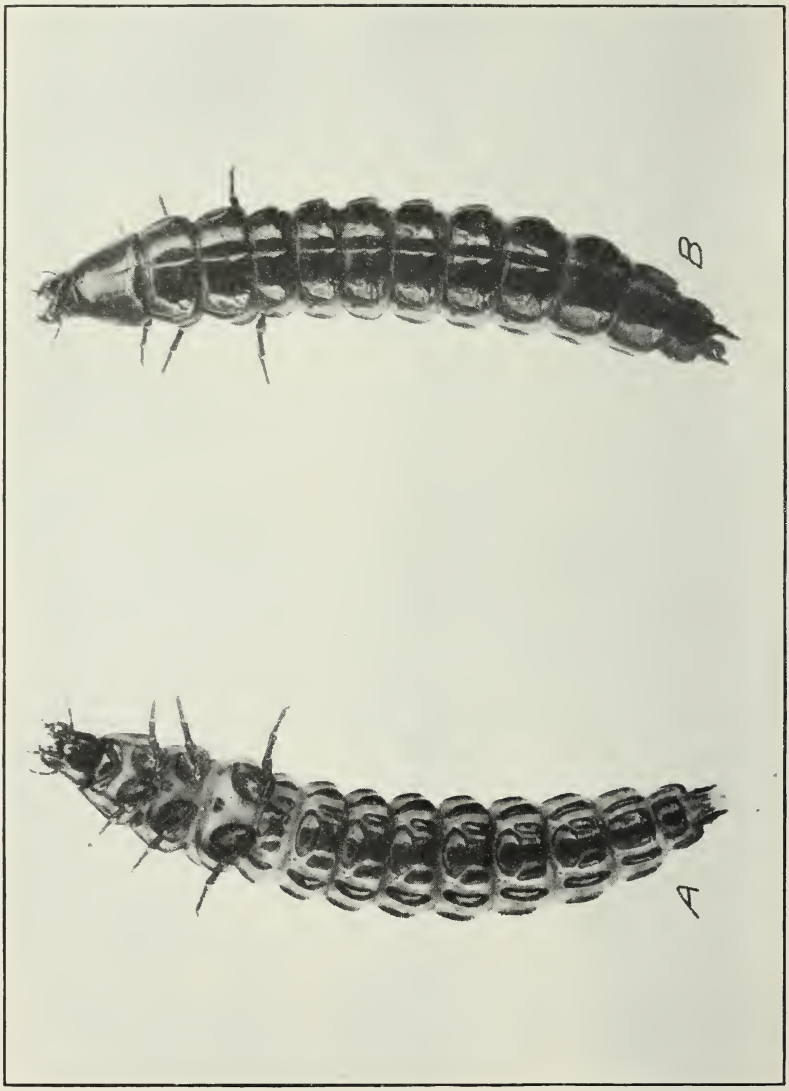
[3] Casey, T. L. Coleopterological notices. *In* Ann. N. Y. Acad. Sci., v. 9, pp. 285–683, 1896–1897.

[4] It might be added that Colonel Casey in the paper cited above also proposed several names of subspecies represented in his collection. These were *C. stellata*, a Lake Superior form of *calidum; expansa*, another form of the same species from Iowa; and *laticollis*, a third from Las Vegas, N. Mex. A form of *sayi* from Norfolk, Va., he considers as *virginica*, one of *frigidum* from Indiana as *levettci*, and one of *obsoletum* from New Nexico as *microsticta*. He also states that "*pimeliodes* Walk., *zimmermanni* Lec., and *striatula* Lec., are distinct species and should not be considered subspecies of *luxata*."



WHERE THE LIFE HISTORY OF CALOSOMA BEETLES WAS STUDIED.

Interior view of one of the outdoor insectaries at Melrose Highlands, Mass., where studies were made on the life histories of many species of Calosoma. (Burgess.)



CARABUS LIMBATUS.

A.—Third-stage larva, ventral view, ×4. *B.*—Same, dorsal view, ×4. Note difference in form of this larva from that of Calosoma and the different shape and arrangement of the ventral plates. (Original.)

Of the species described by Mr. H. C. Fall[1] in 1910, namely, *eremicola*, *parvicollis*, and *tristoides*, the writers have seen a representative of the last only, which is mentioned above. The other two could not be added to the table for separating the species, as the characters of the male tarsi are not given in the description.

TABLE FOR DETERMINING ADULTS OF CALOSOMA.

Anterior tarsi of male with joints 1–4 hairy beneath.
Thorax with sides broadly flattened behind; body elongate, black.
Elytra deeply striate, with blue border........................1. *externum.*
Elytra smooth, with a few punctures on the basal half..........2. *macrum.*
Elytra with series of fine punctures..........................3. *protractum.*
Thorax narrowed behind, sides not flattened; elytra deeply striate.
Elytra gold-green with red margin.
Larger; middle tibiæ of male curved and with a dense brush of hairs on the inner surface near the tip......................4. *scrutator.*
Smaller; middle tibiæ of male straight, not hairy..........5. *wilcoxi.*
Elytra black to slightly bronze, with three rows of small greenish-bronze punctures..6. *frigidum.*
Elytra coppery to greenish-bronze, with coppery-green margins; punctures same shade as elytra.
(Europe, introduced into Massachusetts)................7. *inquisitor.*
Anterior tarsi of male with joints 1–2 only hairy beneath.
Thorax trisinuate behind, elytra deeply striate with three rows of golden foveæ...8. *sayi.*
Anterior tarsi of male with joints 1–3 hairy beneath.
Green species with underside of body bluish-black or greenish-black; elytral spots faint and same color as elytra.
Elytra deeply and regularly striate.
(Introduced and established in New England)...........9. *sycophanta.*
Elytra reticulate, granular.
(Europe, introduced into Massachusetts)...............10. *reticulatum.*
Black species without golden spots (faint bluish-green spots in *obsoletum*); striæ of elytra faint and obliterated behind (except in *angulatum*).
Elytra narrowly margined:
Side margin of thorax meeting the base in a well-defined angle (except in *parviceps*).
Head coarsely punctured, thorax strongly angulated at the sides.
Elytra deeply striate from base to apex.........11. *angulatum.*
Elytra faintly striate from base to apex........12. *peregrinator.*
Elytra faintly striate on basal half, becoming obliterated towards apex.
Thorax strongly angled at sides...........13. *prominens.*
Thorax arcuate at sides....................14. *parviceps.*
Head with a few coarse punctures in front.
Elytra with coarse transverse punctures near base..15. *lugubre.*
Head smooth; thorax narrowly margined.
Elytra nearly smooth, oval; wings feebly developed.16. *palmeri.*
Side margin of thorax meeting the base in a curve.
Thorax slightly bisinuate behind.
Basal impressons slight; elytra nearly smooth........17. *triste.*
Basal impressions broad; elytra with scaly sculpture. 18. *obsoletum.*
Thorax emarginate behind, hind angles broad, prolonged.
Without luster; transverse basal grooves of elytra as prominent as longitudinal striæ..........................19. *semilaeve.*
Without luster; transverse basal grooves of elytra not as promiinent as longitudinal striæ......................20. *simplex.*
Elytra smooth, more broadly margined, oval; wings wanting (form robust, nearly as in *triste*)..21. *haydeni.*
Elytra smooth, more broadly margined, oblong-oval; wings well developed (form robust and posterior angles of thorax not as broadly reflexed as in *triste*)..22. *tristoides.*

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[1] Fall, H. C. Miscellaneous notes and descriptions of North American Coleoptera. *In* Trans. Amer. Ent. Soc., v. 36, pp. 89-197 (pp. 90-92), 1910.

Black species with golden or greenish-golden spots. (Spots sometimes faint in *tepidum* and *morrisonii*).
Thorax with broad basal impressions; elytral striæ regular....23. *calidum.*
Thorax with small basal impressions; elytral striæ frequently confused or faint.
Elytra of smooth sculpture, without imbricated appearance. 24. *morrisonii.*
Elytral striæ of medium depth and frequently confused..25. *tepidum.*
Elytral striæ fine, imbricate or transversely rugose. (Europe.)..................................26. *auropunctatum.*
Bronzed species with three rows of chainlike elevations on the elytra; striæ confused.
Thorax less narrowed behind.
Basal impressions broad; wings well developed; elytra oblong-oval. 27. *cancellatum.*
Basal impressions shallow; wings wanting; elytra oval, less deeply sculptured.......................................28. *subaeneum.*
Thorax more narrowed behind; basal impressions small; wings wanting; elytra oval...29. *moniliatum.*
Bronzed species without three rows of chainlike elevations; with three rows of depressed greenish-golden spots.
Body elongate, tibiæ of mesothorax and metathorax of male curved. (Japan; introduced into Massachusetts and New Hampshire). 30. *chinense.*
Black species with oval or rounded oval elytra, and without wings; thorax emarginate behind with the angles produced.
Outer joints of antennæ pubescent as usual:
Elytra broadly oval, with rows of close-set punctures and intermediate rows of more distant punctures...........................31. *discors.*
Outer joints of antennæ pubescent only along the sides.
Elytra longer, oval, striæ confused, with three dorsal rows of larger punctures..32. *wilkesii.*
Elytra broadly oval, with distant rows of faint punctures; sculpture scaly, sometimes nearly smooth.
Hind angles of thorax not broadly rounded, sculpture rather rough. 33. *luxatum.*
Hind angles of thorax broadly rounded, sculpture smooth. 34. *latipenne.*

TABLE FOR DETERMINING CALOSOMA LARVÆ.

The table which follows gives characters for separating larvæ of different species of Calosoma. Full-grown specimens were used, as more satisfactory determinations can be made with them than with the earlier stages. The larvæ must have molted 24 hours or more before an attempt is made to classify them, otherwise the colors will not be normal. In order to show the difference in appearance of larvæ of this genus from those of Carabus, an illustration (Pl. VI) is given of a third-stage larva of *Carabus limbatus.* All measurements of larvæ have been made as follows: The length has been taken from the base of the mandibles to the posterior border of the anal segment, and the width has been measured at the middle of the mesothoracic segment.

The writers realize that this table is incomplete, but it covers the species which they have been able to study and is published at this time in the hope that it may assist anyone who wishes to determine some of the more common larvæ of Calosoma.

With reddish-brown patch at base of caudal appendages in second and third stages.
Dorsum shining black in all stages except *scrutator*, which is sometimes brownish-black. Full-grown larvæ more than 30 mm. long.
Anterior ventral plate of first to seventh abdominal segments oval without noticeable dilation on anterior middle margin. Outside posterior ventral plates of same segments round without broad notch on inner

side. Posterior median plates rather oval in form save on sixth and seventh segments, where they appear somewhat truncate on inner margins; plates with broad median line of separation in well-fed larvæ. Posterior angles of anal segment pointing backward rather prominently. (Pl. XI, B.)

(Introduced and established in New England).......... *C. sycophanta.*

Anterior ventral plate of first to seventh abdominal segments oval, with noticeable dilation on anterior middle margin. Outside posterior ventral plates of same segments round to approximately square, often with broad and shallow notches on inner margins. Posterior median plates square to rectangular, truncate on inner margins of first 7 segments, plates with narrow median line of separation in well-fed larvæ. Posterior margin of anal segment truncate, posterior angles not pointing prominently backward. (Pl. IX, B.)

(Eastern, southern, and central United States and Canada). *C. scrutator.*

Dorsum brown to blackish-brown in second and third stages. Full-grown larvae less than 30 mm. long.

Caudal appendages stout, almost straight. Dorsal protuberances prominent, erect, located two-thirds length from base to apex.

Posterior angles of anal segment obtuse, not prominent and not protruding prominently backward.

(Eastern, southern, and central United States).......... *C. wilcoxi.*

Posterior angles of anal segment acute and extending backward rather prominently.

(Europe, introduced into Massachusetts)............. *C. inquisitor.*

Caudal appendages long, acute, usually slender. Dorsal protuberance short, stout, pointing slightly backward, located about one-half length from base to apex.

(Northern United States and Canada).................... *C. frigidum.*

Without reddish-brown patch at base of caudal appendages in second and third stages.

Dorsum bronze to blackish-bronze in all stages; more prominent in second and third.

Caudal appendages very long, slender, slightly curved upward.

(Japan).. *C. chinense.*

Dorsum dull or shining black in all stages.

Caudal appendages short (less than 2 mm.), stout, curved slightly downward from base to apex.

Anterior ventral plates of first to seventh abdominal segments dilated at center, especially on anterior margins.

Posterior median plates of abdominal segments 2 to 7 inclusive with both median anterior and posterior angles rectangular.

Dorsal protuberance of caudal appendages stout, acute, rather erect, located in middle. Posterior angles of anal segment almost truncate. Larva robust. Dorsum dull black.

(Northern, eastern, and central United States and Canada. *C. calidum.*)

Dorsal protuberance of caudal appendages stout, acute, rather erect but located two-thirds length of appendage. Posterior angles of anal segments acute. Larva rather elongate. Dorsum shining black.

(Rocky Mountain section and southwestern United States.) *C. obsoletum.*

Posterior median plates of abdominal segments 1 to 6 inclusive with median anterior angles rectangular and posterior angles rounded.

Dorsal protuberance of caudal appendage short, stout, rather erect. Abdominal segments 1 to 8 each containing from four to ten small plates near lateral apices of anterior ventral plate.

(Pacific slope, Rocky Mountain section and the southwestern United States) .... *C. cancellatum.*

Dorsal protuberance of caudal appendage rather long, stout, extending backward in a straight line from basal half of appendage. Abdominal segments 1 to 8 each containing from two to five small plates near lateral apices of anterior ventral plate.

(California and Idaho)........................ *C. semilaeve.*

Anterior ventral plates of first to seventh abdominal segments not dilated at center.
  Plates with a prominent notch in center, anteriorly and sometimes posteriorly.
    (Southern and central United States).............. *C. lugubre.*
  Plates without notch in center anteriorly.
    Lateral plates somewhat circular in form; ventral plate on eighth abdominal segment somewhat rectangular, considerably broader than long; middle posterior notch in above plate obsolete or slightly marked—not as prominent as other two posterior notches.
      (Europe, introduced into Massachusetts)... *C. reticulatum.*
    Lateral plates elongate in form; ventral plates on eighth abdominal segment nearly square, middle posterior notch well marked and usually as prominent as other two posterior notches.
      (Europe)................................ *C. auropunctatum.*
Caudal appendages long (2 mm. or more), slender, straight, not bent downward beyond dorsal protuberance.
  Caudal appendages very long (2.5 mm.), slender and straight; dorsal protuberance short, not prominent; posterior angles of seventh and eighth abdominal tergites obtuse.
    (Eastern, southern, and central United States)....... *C. externum.*
  Caudal appendages long (2 mm.), slightly angled downward beyond dorsal protuberance; posterior angles of anal segment and seventh and eighth abdominal tergites rather sharply pointed. Larva robust.
    (Western and southern United States)............ *C. peregrinator.*
  Caudal appendages straight, long (2 mm.), straight beyond dorsal protuberance; posterior angles of anal segment obtuse, almost truncate; angles of tergites on seventh and eighth abdominal segments obtuse. Larva long, slender.
    (Rocky Mountain section and southwestern United States.) *C. haydeni.*

GENERAL REMARKS.

On the following pages will be found a consideration of each species of Calosoma as it occurs in the foregoing table. The original description of the species is given, and also a statement concerning its distribution as secured from the literature and information furnished by curators and entomologists in charge of museums or collections of insects from all parts of the United States and Canada. The published information concerning each species is summarized and the results of the investigations which the writers have made dealing with the feeding habits, reproduction, and life history, are included and a bibliography of each species concerned.

Following the species given in the table have been added *Calosoma aurocinctum. C. dietzii, C. maximowiczi,* and *C. splendidum,* as these have been examined by the writers and have been found in greater or less numbers in the United States. They have not been placed in the table, as no male specimens were available for study.

MEASUREMENTS OF PUPÆ.

All measurements of pupæ that are given in descriptions were taken from the anterior margin of the prothorax to the end of the anal segment, and the width was measured at the center of the first abdominal segment.

CALOSOMA EXTERNUM (Say).

(Syn.: *C. longipenne* Dej.)

ORIGINAL DESCRIPTION.

East, Middle, South and Central States. Winged, black, margined with purplish; elytra with three series of obsolete punctures. Length one inch and three-twentieths.

Body elongated, deep black; antennæ brown at tip; thorax punctured, margined with bluish-purple; lateral edge regularly curved to the base; dorsal and basal lines distinct; basal angles obtusely rounded; elytra striate; striæ well impressed, much narrower than the interstitial lines, and with conspicuous, definite punctures; interstitial lines convex, equal, the 4th, 8th, and 12th each with a series of obsolete small punctures, which do not interrupt them; exterior margin bluish-purple.

A large species, brought from Arkansas by Mr. Thomas Nuttall. It somewhat resembles *C. sylvosus*, but is larger, the striæ of the elytra are much more regular, exhibiting nothing of the granulated appearance of those of that insect, and the curve of the exterior edge of the thorax is regular, or without any tendency to excurvature near the base.

EARLY RECORDS OF THE SPECIES.

This species was described by Thomas Say in 1823 from a specimen collected in Arkansas. Later Dejean discovered that *Carabus externus* Say and *Calosoma longipenne* Dej. were synonyms. Some valuable notes on the habits of both adults and larvæ have been recorded by Dr. L. O Howard and Prof. Lawrence Bruner.

DISTRIBUTION.

This species occurs in Arkansas, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Iowa, Kansas, Kentucky, Maryland, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, and Texas. It is more common in the southern range.

COLLECTIONS AND SHIPMENTS.

Messrs. E. A. Schwarz and H. S. Barber, of the Bureau of Entomology, have collected at electric lights in Washington, D. C., and forwarded living specimens for study at the laboratory. In 1909 a female was received May 18 and a male June 7. June 19, 1910, one live female was received from Prof. C. E. Sanborn, Stillwater, Okla. In 1911, 6 males and 8 females were received from Washington, D. C., and in 1912 one pair of beetles was forwarded from the same locality.

HABITS OF ADULTS.

A small experiment conducted in June, 1911, to test the climbing habits of the adults showed that they are fairly agile on the bark of trees. They run swiftly on the ground and climb as actively as *C. frigidum.* During the short time the beetles were under observation they did not attempt to climb without being forced, but seemed thoroughly at ease when placed upon the trees.

FOOD OF ADULTS.

This species has been reported by Riley as feeding on the Rocky Mountain locust (*Melanoplus spretus* Uhl.), by Howard as an enemy of the army worm (*Cirphis unipuncta* Haw.), and by Bruner as feeding on *Lachnosterna* sp.

Daily records were kept of one pair of adults in 1909 from July 1 to August 23, when the male died. The female died July 26. The latter was received from Washington, D. C., May 18, and fed greedily upon raw beef until May 25. Caterpillars of *Malacosoma americana* were then supplied until July 1, and large numbers were consumed. One hundred and twenty-six sixth-stage *Porthetria dispar* caterpillars were consumed from July 1 to August 23.

In 1911 two pairs of adults were received from Washington, D. C., June 4, and placed in jars. Their feeding records are shown in Table 1.

TABLE 1.—*Feeding records of two pairs of Calosoma externum, 1911.*

Pair No.	Received and record started.	Ceased feeding.	Females died or entered hibernation.	Fifth and sixth stage caterpillars consumed.			
				Malacosoma americana.	*Porthetria dispar.*	*Estigmene acraea.*	Total.
5061	June 4	July 7	July 7[1]	52	77	....	129
5062	...do.....	Aug. 17[2]	Aug. 17[3]	40	153	27	220

[1] Female died; record closed.
[2] Record closed because of scarcity of food.
[3] Original female died July 5; another added on same date.

The usual custom is to discontinue feeding records when the female dies, but with No. 5062 another female was added on the same date and the record continued as long as food was available. The record was stopped August 17, but the pair was not transferred to a hibernation cage until August 26. Neither of the females included in Table 1 reproduced in 1911, which partly accounts for the comparatively small amount of food consumed, namely 129 and 220 caterpillars, respectively.

One pair of adults (No. 5097) fed in 1912. The female emerged from hibernation May 27 and died August 3; the male died July 24. One hundred and one full-grown caterpillars of *M. americana*, *M. disstria*, and *P. dispar* were consumed during the time and the female deposited eggs during the season.

The records at hand would indicate that the capacity of this species for consuming food is somewhat less than has been found with some other species of the genus. The records of *C. externum* secured are, however, rather incomplete, and more caterpillars would have been destroyed under natural conditions.

REPRODUCTION.

During the season of 1909 one pair of beetles reproduced very sparingly. The male was received June 7 and placed with the female on that date. On June 27 eggs were found in the jar, and on July 1 the pair were noted in copulation and again eggs were seen. They were scattered through the earth in the jar, but only two hatched, and no larvæ were reared.

During 1911 several beetles were received from Washington, D. C., in June and July, but no reproduction resulted that year. The beetles entered hibernation in the fall and lived to emerge in the spring of 1912. Pair No. 5097 produced 15 fertile eggs between June 1 and July 1. Copulation was noted June 1, 9, and 11, and the female died August 3. Female No. 5062 and female No. 5841 each deposited infertile eggs, which were not counted. The eggs were deposited June 7 to July 2, and one of the females died August 6, while the other entered hibernation August 30.

This species, like some of the other species of Calosoma experimented with at the laboratory, reproduced sparingly in jars. The same was true of *C. inquisitor*, *C. auropunctatum*, and *C. wilcoxi*.

LONGEVITY.

The one male and three females that emerged from hibernation in the spring of 1912 were collected in Washington, D. C., in the spring of 1911. All of these adults died in July and August, 1912, which indicates that the species lives at least two full years in the adult stage, as the beetles in question were larvæ and pupæ in the summer of 1910 or earlier and died in the summer of 1912. Three years is probably nearer the age limit of the species under natural conditions.

HIBERNATION.

All the beetles received from various sources in 1909 and 1910 died the same season without entering hibernation. Several adults, however, that were received during the spring and summer of 1911 ceased activity and entered hibernation August 12 and 26 and September 5. The same beetles emerged in the spring of 1912 on May 27 and 28 and June 3. The cavities, so far as could be determined, ranged from 1 to 3 inches deep. Three males and four females entered hibernation in the fall of 1911 and one male and three females emerged the following spring.

Adults of this species hibernated successfully at Melrose Highlands, Mass., through the winter of 1911–12, one of the most severe in this section for many years, which proves their hardiness when food and other conditions are favorable.

THE EGG.

Ten fresh eggs gave the following average measurements: Length, 5.4 mm.; width, 2.5 mm. They are somewhat elliptical in form with a slight taper toward one end. The color is white with a faint yellowish tinge. They vary greatly in form, ranging from long and almost cylindrical, tapering slightly at both ends, to short, oval, and somewhat kidney-shaped.

About 100 eggs were deposited by three females in 1912 but only 12 of these hatched. The fertile eggs were deposited June 4, 5, and 12, and 8 to 13 days were required for hatching. These records indicate that 8 or 9 days is the average time the eggs require for hatching during June.

DESCRIPTION OF LARVA.

First stage.—Form short, stout. Average length of 7 specimens, 7.7 mm.; width, 2.9 mm. Caudal appendages straight, very long (2.5 mm.), slender, bearing numerous short spines. Color black above, ventral plates dark to grayish-brown.

Second stage.—Form short, very broad. Average length of four alcoholic specimens, 13 mm.; width, 4 mm. Caudal appendages very long, the same length as in first stage but somewhat larger. Protuberance small, located about one-half the distance from base to tip. Ends of tergites, viewed from ventral side in partially fed larvæ, projecting well laterad, posterior angles of same obtuse and projecting prominently backward. Posterior angles of last segment short, rather acute. Color same as in first stage.

Third stage.—Form robust. Length of one alcoholic specimen, 20.5 mm.; width, 6.5 mm. Caudal appendages long, slender, spreading widely apart at tips. Protuberance short, acute, making angle of 45° with appendage, and located slightly more than one-half distance from base to tip. Tergites not protruding as far laterad in partially fed larvæ as in second stage. Color dull black on dorsum, ventral plates dark brown to grayish brown. No reddish-brown patch at base of caudal appendages in second and third stages.

TIME REQUIRED TO COMPLETE LARVAL STAGES.

The time required to pass through the different larval stages was only secured with the first two, as all larvæ failed to live through the third stage. Three larvæ hatched June 24, 1912, and died July 6, 9, and 11, while in the third stage. Two of these larvæ molted to second stage on the third day after hatching and one on the fourth. Three to five days were required to pass the second stage and the larvæ all died after 7 and 8 days in the third. An average of these records indicates that 3 days are required to complete the first and 4 days the second stage.

No pupal records could be obtained, as the larvæ died in the third stage.

FOOD CONSUMED BY LARVÆ.

So few larvæ were secured during the series of years these experiments were conducted and so many specimens died that the feeding records are far from complete. Two larvæ, all that hatched in 1909, were fed until both died while in the second stage. The first hatched July 6 and died July 13, consuming in the meantime five sixth-stage caterpillars of *Porthetria dispar.* The second hatched July 13, consumed three sixth-stage caterpillars of *Porthetria dispar* and was found dead July 23.

Records were kept of 12 larvæ that hatched during 1912; most of them died in the first stage but a few lived to reach the second and third. One larva consumed nine fourth-stage caterpillars of *Porthetria dispar* and another destroyed nine pupæ of the same species and died in the third stage.

The records at hand are so incomplete that a definite statement can not be given of the amount of food required by the larvæ. The adults are somewhat larger than those of *C. lugubre,* and it is probable that they require about the same number of medium-sized caterpillars or pupæ for the completion of their growth, or an average of 21. The feeding period probably extends over about 20 to 25 days.

HABITS OF LARVÆ.

During the season of 1912 some notes on the climbing habits of the larvæ were obtained. (Pl. III.)

June 24 two newly hatched larvæ were placed in the experiment. Many observations were made on these during the time they remained in the first stage and they made no attempt to climb. When placed upon the bark they would immediately crawl and wedge themselves under the nearest loose scales, and remain there for hours unless disturbed. In attempting to crawl they usually fell to the ground. The second-stage larvæ maneuvered in about the same manner when placed upon the bark of the tree. One crawled back and forth on a limb but when it attempted to climb up or down the trunk it immediately fell.

Third-stage larvæ were kept in the experiment from July 1 to July 11, when the last died. They were placed upon the trunk of the tree many times but climbed up very little before falling. One specimen crawled as much as 1 foot down the trunk from where it was placed before falling and this was the best record of progress during the experiment.

The larvæ in the three stages were kept under observation in the experiment from June 24 to July 11 without any indications of their having reached the food cage at the top of the tree. It was necessary to supply the larvæ with food on the ground in order to keep them from starving. All the data secured on the habits of the larvæ would indicate that under natural conditions they climb very little if at all. In this respect they possess habits very similar to those of *C. calidum.*

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Page 125, pl. 1, fig. 8. Feeds on the army worm. The larvæ were found in remarkable abundance at Huntsville, Ala., by L. O. Howard under stones and logs; devours worms that creep in for shelter during the day.

1890. Bruner, L. Insects Injurious to Young Trees on Tree Claims. Univ. Nebr. Bul. 14 (Bul. Agr. Expt. Sta. Nebr., v. 3, art. 2), p. 83–149, 98 fig. 1890.

Page 117. Note of this species and *C. lugubre* being attracted to lights and their feeding upon May-beetles.

CALOSOMA MACRUM Lec.

ORIGINAL DESCRIPTION.

Elongated, black, shining, with front part of head scarcely punctate, with thorax one-half shorter than broad, narrowed towards the front, sides rounded, somewhat more broadly reflexed on the posterior, purplish, with truncate base, broadly marked on both sides; elytra scarcely broader than thorax, purplish margined, almost obsoletely striated, and punctures marked in triple series, thickly punctate here and there in front of the middle. Length 1.05 inches.

DISTRIBUTION.

J. L. LeConte described this species in 1853.[1] It occurs in Louisiana and Texas and a single specimen is present in the collection of the California Agricultural Experiment Station labeled "Md."

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[1] LeConte, J. L. Notes on the classification of the Carabidæ of the United States. *In* Trans. Amer. Phil. Soc., v. 10, n. s., pt. 3, art. 27, p. 364–403 (p. 400), 1853.

CALOSOMA PROTRACTUM Lec.

ORIGINAL DESCRIPTION.

Elongated, black, somewhat shining, with thorax twice broader than long, base scarcely notched, somewhat indented, with margin thickened; punctate at base and sides, sides reflexed more broadly posteriorly; elytra a little broader than the thorax, parallel, punctate finely in series. Length 0.95–1.05 [inches]. Arizona. Dr. Irvine, U. S. A.

DISTRIBUTION.

This species was described by LeConte in 1862.[1] It occurs in Arizona, Colorado, Kansas, and Mexico. Dr. F. H. Snow collected specimens at an altitude of 3,750 feet in Arizona.

CALOSOMA SCRUTATOR (Fab.).

ORIGINAL DESCRIPTION.

[Translation.]

Carabus, winged species, with striate elytra, green, with punctures in triple row, thorax dark blue; margin reflexed, golden. Habitat, Virginia. Very like the preceding (*sycophanta*). Thorax violaceous, with rounded margin, somewhat reflexed, golden. Margin of elytra golden. Abdomen green, spotted with gold. It varies sometimes in having abdomen entirely violaceous.

EARLY RECORDS OF THE SPECIES.

This species was originally described by Fabricius in 1775 and the type specimen or specimens were from Virginia. The species was given space under the genus Carabus in this author's other writings on Coleoptera until 1801, when he placed it in the genus Calosoma. This species attracted the attention of other early and prominent writers like Olivier, Latreille, Say, and Dejean. Chapuis and Candèze in 1855 were the first authors to figure and describe the larva. Riley, between 1870 and 1880, frequently wrote of the usefulness of this species as an enemy of the forest tent caterpillar (*Malacosoma disstria*) and cankerworms. Numerous other entomologists of the United States, Canada, and even some of those of European countries, have collected and published many valuable notes on this important economic species.

DISTRIBUTION.

This species occurs in Alabama, California, Colorado, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Massachusetts, Michigan, Mississippi, Missouri, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, Tennessee, Texas, and Virginia. It has also been found in Ontario, Canada, and in Mexico.

COLLECTIONS AND SHIPMENTS.

Through the kindness of Messrs. E. A. Schwarz and H. S. Barber, of the United States National Museum, many specimens of this species, along with specimens of *C. wilcoxi* and *C. externum*, have been received at the gipsy moth parasite laboratory for study and experimental work. All of the material shipped by these collectors was taken at electric lights in Washington, D. C. One live female was received from Prof. C. E. Sanborn, Stillwater, Okla., in 1910. Others were collected by Messrs. J. V. Schaffner, jr., at Dover, Mass., A. M. Wilcox, at Cohasset, Mass., and N. W. Souther, at Onset, Mass.

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[1] LeConte, J. L. Notes on the species of Calosoma inhabiting the United States. *In* Proc. Acad Nat. Sci. f. 1862, v. 14, p. 52–53, 1863.

From 1909 to 1912, 82 males and 98 females were received. Those collected in Washington, D. C., arrived between May 12 and July 8, and most of them reached Melrose the last half of May. The Massachusetts specimens were collected in June, July, and August.

HABITS OF ADULTS.

In the climbing experiment (Pl. III) a pair of adults when released proceeded directly to the base of the tree and then to the top. After climbing around the tree a few times with great ease and swiftness the pair were seen in coitu on the side of the trunk.

On June 16, 1911, 7 males and 6 females were released in a greenhouse at Brighton, Mass., where *Asparagus plumosus* is grown. Some of the beetles were placed upon the asparagus stems and leaves to ascertain if they could climb these small and slippery stems. One female climbed to the top of one plant which was about 15 feet high, then continued up the twine, around which the plant grew, about 8 feet farther to where it was fastened, and was then lost to view. Another adult ascended to the top of a plant and remained on a leaf for a short time.

May 28, 1909, 24 males and 33 females were placed in a large compartment of an outdoor cage to observe their habits of climbing and feeding. The cage was covered with fly-screen wire and measured 2 by 4 by 8 feet high. Caterpillars were supplied daily for food and the following notes were secured:

June 2, Mr. Burgess observed the beetles in the foregoing cage until 9 p. m. It was a moonlight night but the cage was quite dark as the light was obscured by the laboratory building. At the advent of darkness the beetles became very lively and ran about on the walls of the cage. They also flew about in the cage and were more active than during the day, at which time they usually remained at the top. Several were noted feeding upon caterpillars on the side of the cage. They did not appear to hunt the caterpillars as much as did *C. sycophanta* but when one crawled by they seized and devoured it greedily. The beetles would cling to the side of the cage head down and hold the caterpillars in their mandibles while feeding and occasionally carried them about in their jaws for some time before finishing them. (Fig. 4.) A considerable percentage of the caterpillars were killed and devoured by the beetles in this cage during the night. After dark the beetles made a droning noise, probably by moving the wings rapidly, which was audible for quite a distance from the cage.

Larvæ of *C. scrutator* were observed crawling about in this cage at various times during the summer. They attacked the largest caterpillars on the ground but were not seen climbing on the sides.

FOOD OF ADULTS.

These beetles have been reported as feeding on the following species of insects: Cankerworms, tent caterpillars, army worms, (*Hibernia*) *Erannis tiliaria* Harr., (*Aletia*) *Alabama argillacea* Hbn., and (*Cacoecia*) *Archips fervidana* Clem.

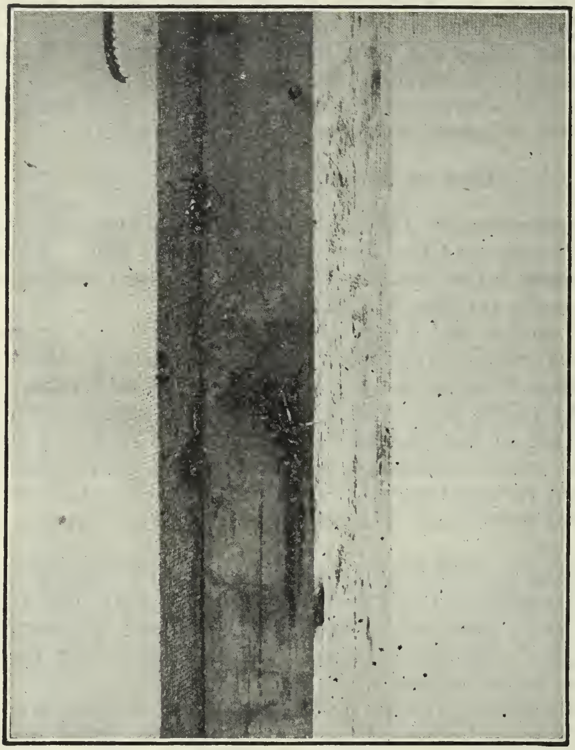


FIG. 4.—*Calosoma scrutator* feeding on a caterpillar in a large cage. (Original.)

April 1, 1910, the following note was taken from a letter received from Mr. J. J. Davis: "Several years ago at an electric light at Urbana, Ill., I noticed the species *Calosoma scrutator* actively engaged in eating the June beetles as they would light on the pavement." No attempts were made at the laboratory to ascertain the number of different species of insects upon which the beetles would prey. Daily feeding records (see Table 2) were kept of four pairs of adults received about the middle of May, 1909, the beetles being supplied with such food as was most available at that time. The beetles were offered raw meat, of which they partook sparingly until about May 25, when the caterpillars of *Malacosoma americana* had reached a fair size. The daily records were then started and continued until the beetles either died or entered hibernation in the fall.

TABLE 2.—*Feeding records of four pairs of Calosoma scrutator, 1909.*

Pair No.	Feeding record started.	Ceased feeding.	*Malacosoma americana*, third to sixth stages.	*Porthetria dispar*, sixth stage.	*Hyphantria cunea*, third to sixth stages.	Total.
1772	May 16	Sept. 24[1]	315	257	143	715
1786	26	July 23[2]	234	42	....	276
1787	23	27[3]	336	138	....	474
1789	26	Sept. 18[4]	277	194	97	568
Average...		....	....	....	....	508

[1] Female died Aug. 11.
[2] Female died June 26.
[3] Female died July 16.
[4] Male died Aug. 25.

All the pairs cited above reproduced as is shown in Table 4; this accounts for the enormous amount of food eaten, which averaged 508 caterpillars per pair. The writers believe that the average would be slightly lower than this if more experiments had been conducted, especially if some of the females did not oviposit. In two of the experiments the beetles fed unusually late and the records were started somewhat earlier than the normal time of activity in New England. The average feeding period of this species about Washington, D. C., is probably from May 15 to Sept. 1 or 15, and in New England from June 1 to Sept. 15.

From a lot of larvæ that hatched September 23, 1909, two pairs of adults issued from cavities at the bottom of jars between November 16 and 21, and immediately came to the surface in search of food. The beetles were kept in jars of earth in the laboratory at a temperature of about 72° F., during the day. Various living insects were offered for food and none of them was refused. The feeding records are given in Table 3.

TABLE 3.—*Feeding records of two pairs of young adults of Calosoma scrutator, fall of 1909.*

Pair No.	Insects eaten.	Number.	Pair No.	Insects eaten.	Number.
2857	*Alsophila pometaria*	[1] 4	2558	Full-grown *Pontia rapæ* caterpillars	22
	Full-grown *Carpocapsa pomonella* larvæ	12		Full-grown *Tenebrio molitor* larvæ	23
	Full-grown *Pontia rapae* larvæ	29			
	P. rapæ pupa	1			
	Full-grown *Tenebrio molitor* larvæ	31			
	Total	77		Total	45

[1] Females.

On December 15 all the beetles buried themselves in the earth for hibernation and the jars were transferred to the laboratory cellar where they remained until the following spring. In this experiment the beetles came to the surface and fed as soon as they entered the adult stage. Adults of *C. sycophanta* seldom do this, but remain in the pupal cavity until the following spring. In feeding, the beetles showed no preference for the species mentioned in Table 3. These were supplied because they could be most easily secured.

This record was obtained under laboratory conditions and would not apply under natural conditions in New England. It indicates that late fall emergence of the beetles may take place in the southern range.

REPRODUCTION.

The largest number of eggs deposited in a single season by one female was 396. Records were kept of five pairs that reproduced in 1909 to show the number of eggs deposited daily by each female. These records are given in Table 4.

TABLE 4.—*Record of eggs deposited by five pairs of Calosoma scrutator, 1909.*

Date.	Pair No. 1772.	Pair No. 1786.	Pair No. 1787.	Pair No. 1789.	Pair No. 2704.	Date.	Pair No. 1772.	Pair No. 1786.	Pair No. 1787.	Pair No. 1789.	Pair No. 2704.
June 14	......	......	42	......	......	June 29	......	7	52	20	24
17	......	......	1	......	......	30	......	......	19	2	......
18	......	......	18	......	......	July 1	......	......	2	......	4
19	......	......	30	1	......	2	4	......	11	20	36
20	......	......	10	15	......	3	4	......	......	......	1
21	38	......	42	67	25	9	1	......	......	......	......
22	......	4	57	40	13	15	......	......	......	......	11
23	68	......	22	27	33	16	......	......	(1)	......	......
24	......	30	14	9	19	19	......	......	......	......	17
25	......	17	11	2	......	Aug. 1	......	......	......	......	(1)
26	46	......	35	31	19	11	(1)	......	......	(2)	......
27	......	18	30	......	3						
28	......	8	......	......	......	Total..	161	84	396	234	177

(1) Female died. (2) Female entered hibernation.

After the females had ceased oviposition at the end of the season the males in each of the four jars died. They were replaced with males from the same shipment, but all the females died soon after, except one (No. 1789) which entered hibernation and again laid eggs in 1910. This female deposited 26 fertile eggs in 1910 and died during the summer. Table 4 is inserted to show the duration of oviposition each year and indicates the large number of eggs sometimes deposited by a female in a single day.

The total number of fertile eggs deposited by two females in 1910 was 81. There were other females in stock but they did not deposit eggs. Other beetles received during the first days of June and July, 1911, did not deposit eggs that year.

LONGEVITY.

One female that was received from Washington, D. C., May 18, 1909, lived until July 21, 1910. This adult reproduced in both 1909 and 1910 and a few other specimens lived as long as this female, but no record was kept concerning reproduction. The age of these beetles was unknown at the time they were received but most of the specimens lived two years in confinement.

It is probable that the length of life is considerably greater under natural conditions.

HIBERNATION.

The notes at hand on the hibernation of this species present some great variations as to the time of entering and emerging. Of the beetles received in the spring of 1909, those that lived until the fall entered hibernation between September 8 and October 12. The first female of this lot emerged May 9, 1910, and one on each of the following dates: May 26 and June 4, 12 and 16. One male emerged June 30. The depth of the cavity of only one female could be determined and this was 1 inch below the surface.

One pair of beetles collected at Onset, Mass., during August, 1909, reproduced during the latter half of September and entered hibernation October 8. The female died during the fall or following winter and the male was unearthed from a cavity 9 inches deep in the hibernation cage June 23 the following summer.

Two pairs of young stock, reared in the fall of 1909 from the parents cited in the preceding paragraph, entered hibernation on December 16 in jars of earth kept in the laboratory. These jars containing the pairs were transferred to the laboratory cellar which retains a temperature of from 30° to 50° F. during the winter. At the advent of spring these jars were again transferred to a shelf in an outdoor cage. The beetles hibernated in cavities at the bottom of large battery jars and could be seen from the outside. The females emerged July 6 and 11, respectively, and until July 18 the males had not shown any signs of activity, at which time they were removed from their cavities and placed on the surface. One of the females died during the summer of 1910, and the remaining two males and one female reentered hibernation September 7 and 13. None of these lived to emerge in the spring of 1911, but two of the males were found dead, 3 and 8 inches deep in the earth.

It appears from the foregoing notes that one might expect normal adults of this species in New England to enter hibernation from September 1 to 15 and emerge the following spring from June 1 to 15, depending entirely upon the season.

The cavities ranged in depth from 1 to 9 inches in loose loam such as was used in the foregoing experiments.

THE EGG.

[Pl. VII, *A*.]

The average length of 8 eggs which had been preserved in alcohol was 5 mm., and the average width 2.3 mm. The largest egg measured was 5.5 mm. long and 2.5 mm. wide. Fresh eggs of this species appear to be somewhat larger than those of *sycophanta*; hence the latter measurements would probably be more correct for fertile eggs soon after deposition.

The eggs are white, with a faint yellowish tinge, nearly elliptical in form, slightly tapering toward one end; in fact, they present the same general appearance as those of *sycophanta*.

The time in the egg stage varied from 3 to 14 days, the general average being 6.84 days as secured from a large number deposited in 1909 by several females. The eggs were deposited between June 4 and July 15. Similar data were secured from the hatching of 81 eggs in 1910, deposited from June 21 and June 24, inclusive. The average time required for the hatching of this lot was five days. Oviposition in the latter case took place entirely during the last days in June when the temperature was more even, and resulted in the development of the eggs in a shorter time. (Pl. VII, *B*.)

DESCRIPTION OF LARVA.

First stage (Pl. VIII, *A*, *B*).—Large, robust larva. Average length of 10 specimens, 9.5 mm.; width, 2.5 mm. Caudal appendages of medium length, rather stout. Color very dark brown to black, ventral plates light brown.

Second stage (Pl. VIII, *C*, *D*).—Form similar to that in first stage. Average length of 8 specimens, 16.9 mm.; width, 4.4 mm. Caudal appendages, short, stout, and straight. Color same as in first stage.

Third stage (Pl. IX, *A*, *B*).—Very large, robust larva. Average length of 10 specimens, 25.6 mm.; width, 5.6 mm. Posterior margin of ninth abdominal segment usually truncate, angles not prolonged. Caudal appendages straight, very stout near base; dorsal protuberance short and acute, located about one-half distance between base and tip. Color very dark brown and black, shining. Ventral plates light brown. Reddish-brown patch at base of caudal appendages in second and third stages.

The foregoing measurements were made from alcoholic specimens, while those of most other species were made from living material.

LENGTH OF TIME REQUIRED TO COMPLETE LARVAL STAGES.

The larvæ that were reared in June and July, 1909, completed the first stage in an average of 3 days; the second in 3 days; and the third in about 15 to the date the larvæ ceased feeding. The whole active period of the larvæ covers about 21 days for the series reared early in the season.

For the series that were reared in the fall of 1909, 4 days were required to pass the first stage, 10 days for the second, and 14 for the third to the date the larvæ ceased feeding, making a total of 28 days for the active feeding period.

The time elapsing between the date the larvæ ceased feeding and the date of pupation was secured from the series reared in the fall of 1909 and seven days were required at a temperature of from 68° to 75° F. The prepupal stage, like the larval stages, is probably shorter in the summer when the temperature is high and other conditions more favorable to development.

FOOD CONSUMED BY LARVÆ.

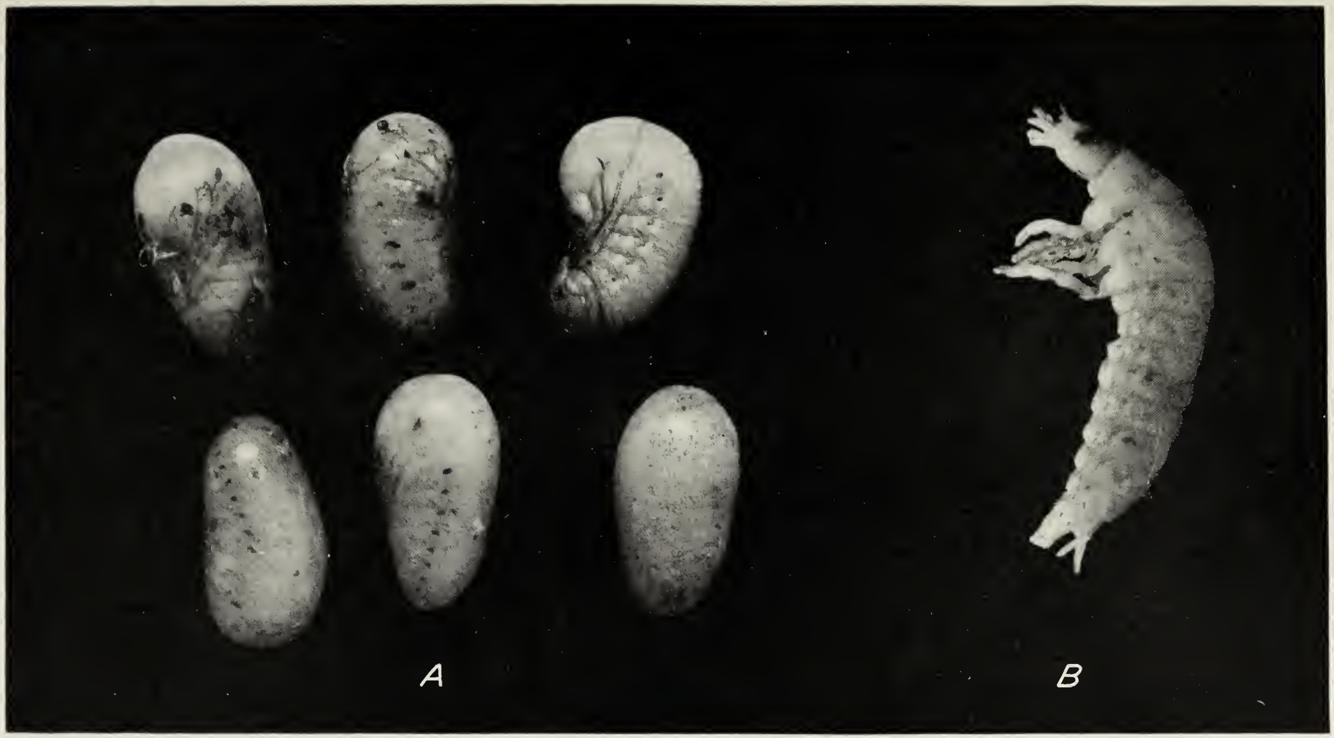
A large series of individual feeding records of larvæ was conducted, using jelly glasses about two-thirds full of earth. Very poor results were secured with such small containers. All of the larvæ in this series died before pupation. The records of six specimens that reached maturity before death are given in Table 5 to show the number of caterpillars destroyed by each.

TABLE 5.—*Food eaten by larvæ of Calosoma scrutator.*

Hatched.	Ceased feeding.	*Malacosoma americana*, fourth and fifth stages.	*Porthetria dispar*, fourth and sixth stages.	Grand total.
1909.	1909.	*Total.*	*Total.*	
June 22	July 9	6	28	34
22	10	4	25	29
22	8	7	38	45
22	21	6	33	39
22	13	5	31	36
22	13	5	31	36
22	14	7	22	29
Average.	....	....	....	36

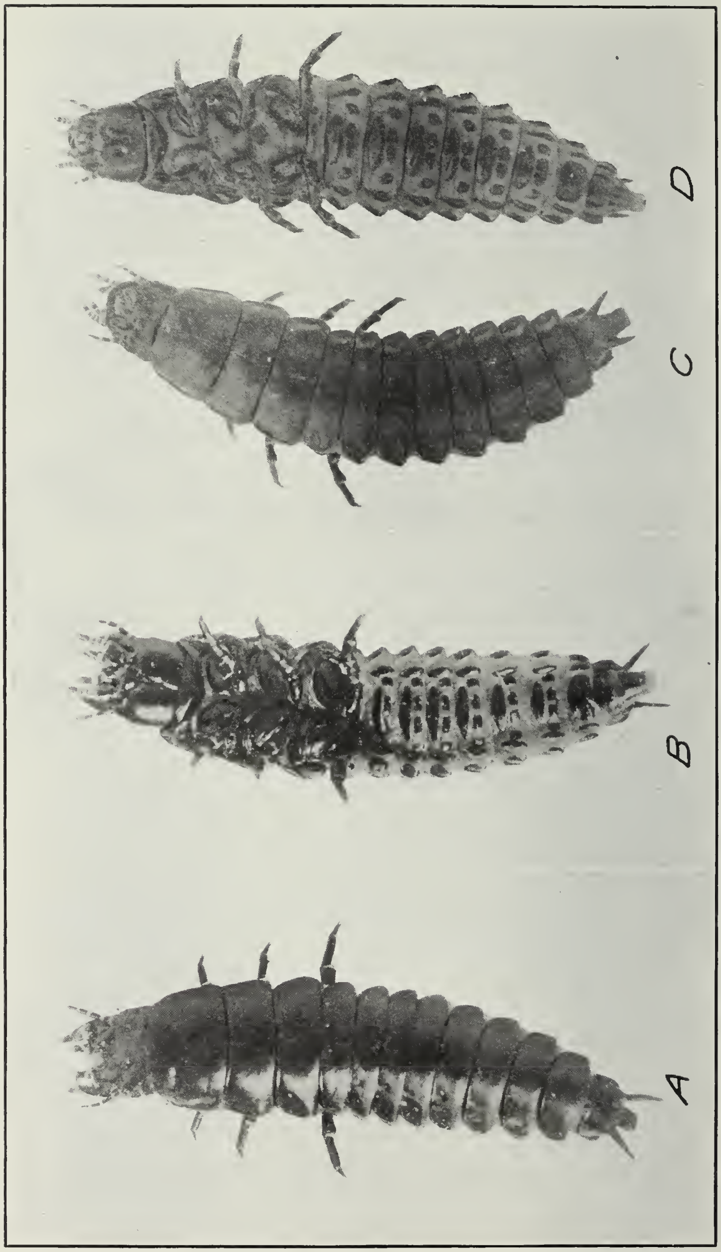
The average number of mostly full-grown caterpillars consumed by each of these larvæ was 36. Using larger jars, giving each larva more freedom, or under natural conditions, the writers believe that larvæ of this species will destroy as many large caterpillars as *C. sycophanta,* which was reported in Bulletin 101 of the Bureau of Entomology to destroy an average of 41. The active feeding period of *C. scrutator* in this series extended over 21 days, and this would have been somewhat longer under more satisfactory conditions.

It was proven in 1912 that these larvæ consume with equal greed pupæ of *Malacosoma americana* and *Porthetria dispar.* One larva that hatched June 24 of that year consumed 31 pupæ of these lepidopterous species while other larvæ consumed 15 to 18 pupæ before becoming full-grown.



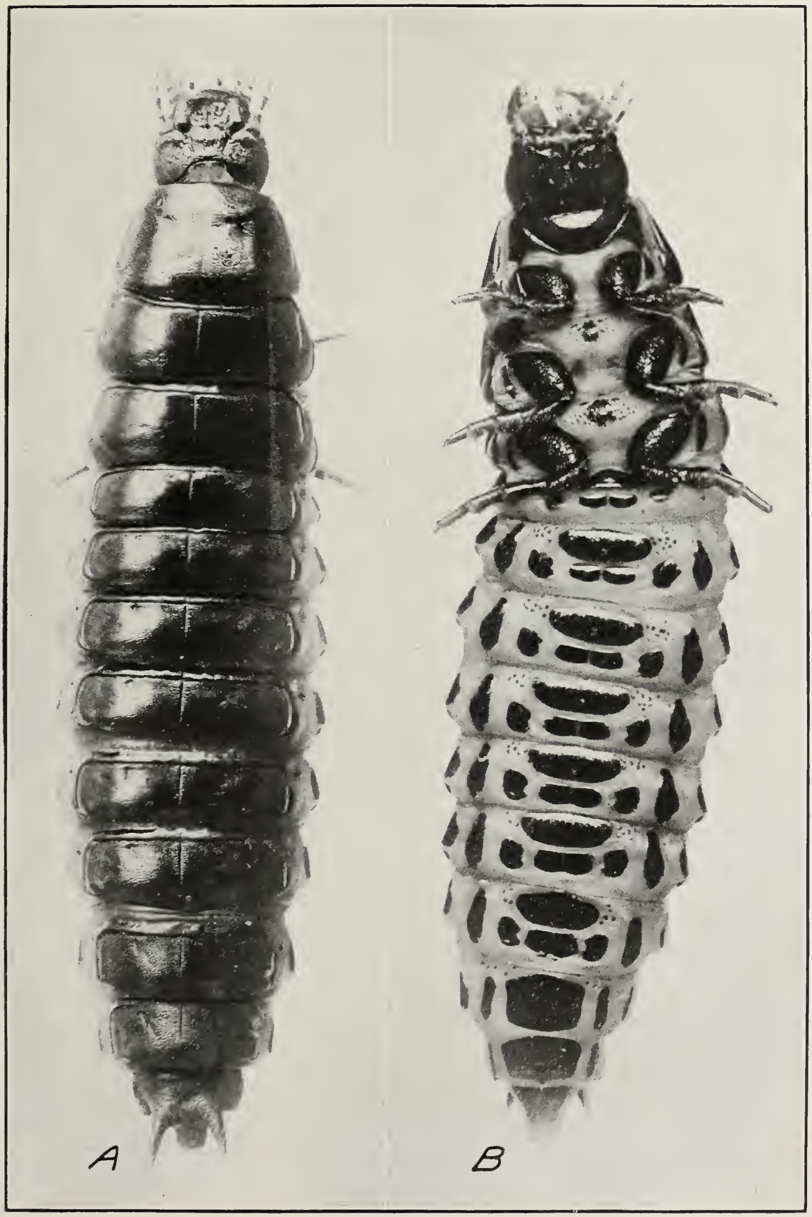
CALOSOMA SCRUTATOR.

A.—Eggs showing different degrees of embryonic development, ×6. *B.*—Newly hatched larva, ×6. (Original.)



CALOSOMA SCRUTATOR.

A.—First-stage larva, dorsal view, ×6. *B.*—Same, ventral view, ×6. *C.*—Second-stage larva, dorsal view, ×4. *D.*—Same, ventral view, ×4. (Original.)



CALOSOMA SCRUTATOR.

A.—Third-stage larva, dorsal view, ×4. *B.*—Same, ventral view, ×4. (Original.)

HABITS OF LARVÆ.

Experiments were tried with larvæ of this species in all stages to secure data on their habits of finding food, using the apparatus shown in Plate III.

June 24, 1912, Mr. Dudley began an experiment with two first-stage larvæ. They were placed several times upon the bark of the tree, as they did not seem to venture there of their own volition. When this was done they would either fall to the ground or advance to the nearest loose scale of bark in their path and remain there until disturbed.

June 26 and 27, the two larvæ molted to second stage. They acted in a similar manner in this stage. They were usually found buried in the earth in the morning instead of in the food cage at the top of the tree.

On July 2, one larva died in the second stage and the other molted. The third-stage larva was put upon the bark of the tree several times and would climb 6 to 12 inches around or down the tree before falling. This larva became rather sluggish by July 12 and was removed from the experiment.

July 16, the junior writer liberated two large third-stage larvæ inside the circle, and observed their movements at intervals for two days, after which time they were becoming exhausted from lack of food. One larva, when placed upon the trunk, ascended 12 inches before falling, which was the best record for distance covered during the period of the experiment.

These experiments were repeated in 1913 with practically the same result, except that in one case a first-stage larva after being placed upon the tree was able to climb about 4 feet before falling. This is the best record made by any larva of this species but hardly indicates that the species commonly climbs to any marked extent.

The movements of these larvæ are very similar in all stages to those of *C. calidum* and *C. frigidum*. It was necessary to remove the larvæ from the experiment at intervals in order for them to feed, indicating that this species must secure food on or near the ground.

COLONY AND CAGE EXPERIMENTS IN GREENHOUSE.

During the early spring of 1910 it was necessary to secure lepidopterous larvæ with which to feed specimens of Calosoma and Carabus after their emergence from hibernation. After much inquiry, a supply was found in a range of greenhouses at Brighton, Mass. The proprietor is a wholesale grower of roses, *Asparagus sprengeri*, and *Asparagus plumosus* and his greatest insect pest on asparagus is a cutworm, *Noctua clandestina* Harr. There are several generations annually and the proprietor and foreman report that the worms can be found in various stages during most of the year. The proprietor resorts to poisoned bran mash and hand picking to combat the pest. He claims an annual loss of $2,500 from this insect which includes $1,000 expended for hand picking at night and other methods, and $1,500 damage as a result of the cutting off of the tender terminals of the plants, which checks their growth.

Cutworms collected by the laborers at night were used to feed Calosoma and Carabus. In return for this act of kindness in forwarding them daily to the laboratory during the early spring, an experiment was started to ascertain if predacious Calosoma could be induced to prey upon the pest.

In June, 1910, five males and three females of this species were placed in one greenhouse, in a wire cage, 2 by 1½ by 1½ feet. A number of asparagus plants were growing in this cage and cutworms were added from time to time.

On August 17, 1910, three adults were climbing about on the sides of the cage. No dead beetles had been removed, nor had there been any reproduction observed by the foreman. The cage was not visited again by the junior writer until March 21, 1911, when two males were active, climbing on the sides of the cage. The foreman stated that the beetles were first active in the cage about February 1, 1911. A dead beetle was removed at that time.

June 16, 1911, the earth in the cage containing the beetles was examined and three males were found in separate well-made cavities at the bottom. The walls of one of the cavities was secured unbroken and the beetles appeared dormant when first disturbed. On this date these beetles had lived in greenhouse temperatures and conditions for one year, thoroughly demonstrating their ability to withstand similar conditions. The foregoing notes show that they do change their habits somewhat to suit conditions, in being alternately active and dormant throughout the year. Two males and two females were replaced in the cage on this date and further observations were made for reproduction of the species in 1911. By August 7, one pair had died and still there was no evidence of reproduction although this might have taken place and the young larvæ escaped through the meshes of the fly screen unnoticed, but it is rather improbable.

On the same date (June 16, 1911) seven males and six females were liberated in the beds of *Asparagus plumosus* in an adjoining house. Some of these beetles were placed upon the asparagus leaves and on these they climbed for a while but soon fell to the ground and disappeared.

June 29 and August 7, 1911, the colony was visited to ascertain if the beetles were reproducing, but no evidence was secured. Neither Mr. Harbeson nor the laborers had seen any of the beetles since they were liberated save one dead specimen that was found about June 25. At this time the men were finding both adults and small cutworms of *N. clandestina.*

June 6, 1912, 3 males and 6 females that had just been received from Washington, D.C., were added to the colony, which now totaled 10 males and 12 females liberated. The colony was visited several times during the year, namely, February 3, April 8, May 29, June 6, and September 25, and examinations made, but there was no evidence that the beetles reproduced.

Although reproduction was not noted with any of the beetles in the greenhouse up to the end of 1912, larvæ might have been present in small numbers.

It is not strange that it did not occur or was unnoticed with so few beetles in a large greenhouse. It is demonstrated in the following paragraph that adults of this species feed upon cutworms during the night when the latter come to the surface of the earth to obtain food, and the writers still have hope that this species may prove a beneficial enemy of cutworms under these conditions. In this case it was possible for the beetles to escape, as the ventilators and doors were frequently left open.

EXPERIMENT TO DETERMINE THE RELATIVE AMOUNT OF FOOD DEVOURED BY ADULTS DURING DAY AND NIGHT.

In connection with the idea of colonizing this species in a greenhouse where cutworms (*Noctua clandestina* Harr.) are abundant several times in the year, it was thought advisable to secure some information on the feeding of this species upon cutworms. Two large battery jars two-thirds full of earth, each containing one male and two females, were used for the experiment. In one jar cutworms were buried in the earth at 5 p. m. and the jar immediately set in a dark closet until 8 a. m. the following morning when the count of devoured and unharmed cutworms was made. All living cutworms were removed until 5 p. m. on this day when they were returned to the jar with others. In the other jar cutworms were buried at 8 a. m. and the count of devoured and living was taken at 5 p. m. They were then removed from this jar until 8 a. m. the following morning. Green grass was placed on the surface of the earth in the jars each time to furnish food for the cutworms and the latter were buried about one and one-half inches below the surface.

The experiment was started June 19 and concluded June 28 because the supply of food was no longer available. After June 24 the cutworms were left in the jars all the time, but records of feeding were made at 5 p. m. and 8 a. m. Fifty-seven full-grown cutworms were devoured by the beetles during the night and four during the day, or 14 times as many were eaten at night as during the daytime. It is evident from these experiments and other jar records that the adults of this species burrow into the ground very little in search of food but take the opportunity to seize their prey whenever it is met (day or night) on or above the surface of the ground. This species destroys large numbers of cutworms as well as arboreal caterpillars.

THE PUPA.

One male pupa of this species measured 20 mm. long and 8 mm. wide. No female pupæ were secured for observation.

Some observations were made upon the change and development of pupæ during the fall of 1909. Some of the larvæ constructed their cavities at the bottom of the jars and next to the sides, which made it comparatively easy to observe their daily changes in appearance. The following notes were secured from a pupa observed at that time:

No. 2884–A. September 23, larva hatched and placed in small jar.
October 3, larva cast first exuvium.
October 16, larva cast second exuvium.
October 23, larva ceased feeding and shortly after that date probably began making cavity. It had made tunnels all through the earth at that time.
October 30, larva pupated in cavity at bottom of jar.
Pupa creamy white and lay on dorsal side. It was observed daily for changes of color, but such changes were very gradual.
November 9, elytra changing to slightly violet color. Eyes could not be plainly seen from the outside. Abdomen still creamy white.
November 12, beetle issued and remained in cavity. Jar filled with earth and transferred to cellar of laboratory where it was allowed to pass the winter. The pupal stage required 13 days in a temperature of from 68° to 75° F.

It is not expected that pupæ mature during the summer in much shorter time than was required in the foregoing experiment, namely, 13 days. In the Southern States, where this species is commonly found, the pupal stage may possibly be two or three days shorter.

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CALOSOMA WILCOXI Lec.

ORIGINAL DESCRIPTION.

Greenish-bronze, blackish-bronze or bronze above, shining with gold and blue below; feet steel-blue; thorax much broader than long, gold-margined; elytra deeply striate, copper margined, spaces between the striæ marked transversely, with punctures marked in triple row. Length 0.77 inch, width 0.4 inch.

Habitat, from New York to Texas, very rare. Very much like the preceding (*scrutator*), but a third smaller, and with thorax a little shorter (and a third narrower), less rounded on the sides behind the middle, slightly retracted; striæ of elytra less deeply but distinctly punctate.

EARLY RECORDS OF THE SPECIES.

This species was originally described by Le Conte in 1848. In his description he mentioned that "it occurs rarely from New York to Texas." In the same year it was listed in his "Descriptive Catalogue of the Geodephagous Coleoptera Inhabiting the United States East of the Rocky Mountains." The description compares this species with *C. scrutator*, which it resembles greatly. In 1862 Le Conte in his "Notes on the species of Calosoma inhabiting the United States" gives descriptive details for separating *wilcoxi* from *scrutator*. The middle tibia of the male of the former species is nearly straight while that of the latter is curved. No published references as to the kind of food sought by these beetles have come to the attention of the writers, save a note by Dr. W. E. Britton, of Connecticut, in his "Tenth Report of the State Entomologist, 1910," in which he states that "Mr. Champlain observed a large ground beetle, *Calosoma wilcoxi* Lec., which was very abundant during the season, feeding upon canker worms."

DISTRIBUTION.

Specimens of this species have been collected in Arkansas, California, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Indiana, Iowa, Kansas, Massachusetts, Michigan, Missouri, Nebraska, New Jersey, New York, Ohio, and Pennsylvania; also in Ontario, Canada. There are records of this species in the Southern States only from Georgia, but it probably occurs in others of them. The collection of the California Agricultural Experiment Station contains specimens from Tulare County of that State, and the species possibly occurs rarely in other far Western States.

COLLECTIONS AND SHIPMENTS.

Entomologists in Washington, D. C., about the last of May and the first of June often observe specimens of *C. wilcoxi* about electric lights in fairly large numbers. Mr. Barber forwarded between May 18 and June 7, 1909, 18 males and 31 females. All were alive except one female. A few other specimens were received from the same source in 1911 and 1912. The writers have been able to secure the data set forth in this paper from the parents collected in 1909.

HABITS OF ADULTS.

The habits of this species in the field are little known to the writers, since they have not had an opportunity to make observations, and the published records are rather fragmentary with reference to this subject. To obtain an idea of their habits two females were placed at the base of the tree (Pl. III) in the climbing experiment, June 14, 1912. Both of these climbed freely and one of the females was found at the top of the test tree the following morning and had consumed two large caterpillars of *Malacosoma americana* that were placed upon it the previous day.

FOOD CONSUMED BY ADULTS.

Of the beetles received in the spring of 1909, five pairs were placed in battery jars and daily records kept of the amount of food eaten. (See Table 6.) The first shipment arrived May 13 and the pairs reserved for feeding and rearing records were offered raw meat for a few days. The beetles partook of this diet rather freely until May 27, when a sufficient number of *M. americana* caterpillars of medium size were secured and substituted.

TABLE 6.—*Feeding records of Calosoma wilcoxi.*

FIVE PAIRS, 1909.

Pair No.	Received from Washington, D.C.	Ceased feeding.	Fifth and sixth stage caterpillars.		Total.
			Malacosoma americana.	*Porthetria dispar.*	
	1909.				
1791	May 18	June 27	67	....	67
1792	18	22	84	....	84
1793	18	24	61	9	70
1794	18	23	66	1	67
1795	18	17	39	1	40

TABLE 6.—*Feeding records of Calosoma wilcoxi*—Continued.

THREE PAIRS, 1910.

Pair No.	Emerged from hibernation.	Ceased feeding.	Fifth and sixth stage caterpillars.		Total.
			Malacosoma americana.	*Porthetria dispar.*	
	1910.				
1791	[1] May 26	July 12	47	17	64
[2] 1792	[2] 23	11	114	17	131
1795	26	11	60	16	76

[1] ♂ Emerged June 4.
[2] June 13 and 22, 4 fertile eggs were deposited.

The records in Table 6 are not normal, as the beetles were received from the South that year. The beetles also ceased feeding early in the season in 1909, as compared with that date for the same beetles in 1910. June 23 was the average date in 1909 and July 11 in 1910. The average number of fifth and sixth stage caterpillars eaten in 1909 was 66, while in 1910 it reached 90, and almost all that were fed in the latter year were in the sixth stage. The average number of large caterpillars consumed by one pair of beetles in two years was 75 each year. There was very little reproduction of this species in confinement, and it is reasonable to expect that they might consume even more food under natural conditions. Ninety caterpillars, such as were fed in Table 6, should equal approximately 250 caterpillars of *Paleacrita vernata* Peck or *Alsophila pometaria* Harr., the latter of which is supposed to form the principal diet of this species in the field. In 1910 the active feeding period of the confined beetles extended over 46 days.

REPRODUCTION.

Close observations were made upon five pairs of beetles received May 18, 1909, through the remainder of the season, but none of this series reproduced that year. Thirteen males and 25 females received somewhat later were placed in a large Riley cage with an ample supply of caterpillars. June 6 one pair was seen in copulation and on June 19 both eggs and larvæ were removed from the cage. Newly hatched larvæ were also found June 20 and 22. Seventeen fertile eggs or larvæ was the total output from the whole supply of beetles in 1909, and these were probably the progeny of the female seen in copulation. One hundred and sixty-four fertile eggs were deposited in 1910 by one or some of the 17 females that emerged from hibernation. The low rate of reproduction, in 1910 at least, was possibly due to the scarcity of males, since only three males lived to emerge from hibernation with the 17 females in the large cage. This does not entirely explain the low egg record secured, as no infertile eggs were found. Females of *C. sycophanta* commonly deposit large numbers of infertile eggs when in confinement without a male, and sometimes do this early in the spring, before their mates have emerged from hibernation.

LONGEVITY OF ADULTS.

Two of the females collected in 1909 died during the spring and summer of 1911. Taking it for granted that they were pupæ in the fall of 1908, they must have spent three years in the adult stage. The males in this same shipment (although they were fewer in number than the females) lived only two years, but under natural conditions they probably live as long as the females, as both sexes of *C. inquisitor* and *C. sycophanta* ordinarily attain approximately the same age before death.

HIBERNATION.

Notes on the hibernating habits of this species are given in Table 7 and the paragraph following.

TABLE 7.—*Showing dates at which Calosoma wilcoxi entered and emerged from hibernation in 1909, 1910, and 1911.*

No.	Date entered, 1909.	Date emerged, 1910.	Depth of cavities, 1910.	Date entered, 1910.	Date emerged, 1911.	Depth of cavities.
			Inches.			*Inches.*
1791	June 27, 1 male, 1 female.	May 26, 1 female		July 12[1]		
		June 4, 1 male				
1792	22, 1 male, 1 female.	May 23, 1 male, 1 female.	1½	July 11, 1 male	Male died in cavity.	2
				14, 1 female died.		
1793	24, 1 male	June 18, 1 male[1]		11, 1 male, 1 female.	Female died in cavity.	6
1795	17, 1 male, 1 female.	May 26, 1 male, 1 female.	1	Aug. 3, male died		

[1] Beetles died during the summer.

The average date of entering hibernation in 1909 was June 23 and in 1910 July 11. The depth at which this species hibernated in soft earth ranged from 1 to 6 inches. In 1909 several specimens were placed in a cage in the laboratory yard, but not all of them emerged in 1910. This was not thought to be abnormal at that time, as some ordinarily die during hibernation, but on May 18, 1911, one female emerged from this same cage. (Fig. 5.) This is an instance where one specimen remained in hibernation two winters and one summer.

THE EGG.

Twelve newly deposited eggs were white with a faint yellowish tinge, and averaged 3.9 mm. in length and 2 mm. in width; in form they were elliptical, occasionally somewhat kidney-shaped, and often tapering toward one end.

Most of the eggs were deposited between June 2 and June 22, 1910, and hatched in from 3 to 12 days. The average time passed in this stage by 168 eggs deposited that year was 6.8 days.

BRIEF DESCRIPTION OF LARVA.

First stage.—Form somewhat stout. Average length of 12 specimens, 7.8 mm.; width, 1.8 mm. Caudal appendages of medium length, straight. Color brown above, ventral plates light brown.

Second stage.—Form stouter than in first stage. Average length of six specimens, 12.9 mm.; width, 2.9 mm. Caudal appendages short and stout. Color slightly lighter than in first stage.

Third stage.—Form robust. Average length of six specimens, 22.2 mm.; width, 4.4 mm. Posterior angles of anal segment obtuse, not prominent or protruding backward. Caudal appendages stout at base; dorsal protuberance short, stout, located two-thirds distance from base to tip. Appendages beyond protuberance slender and pointed. Color chestnut brown above. Ventral plates amber. Reddish-brown patch at base of caudal appendages in second and third stages.

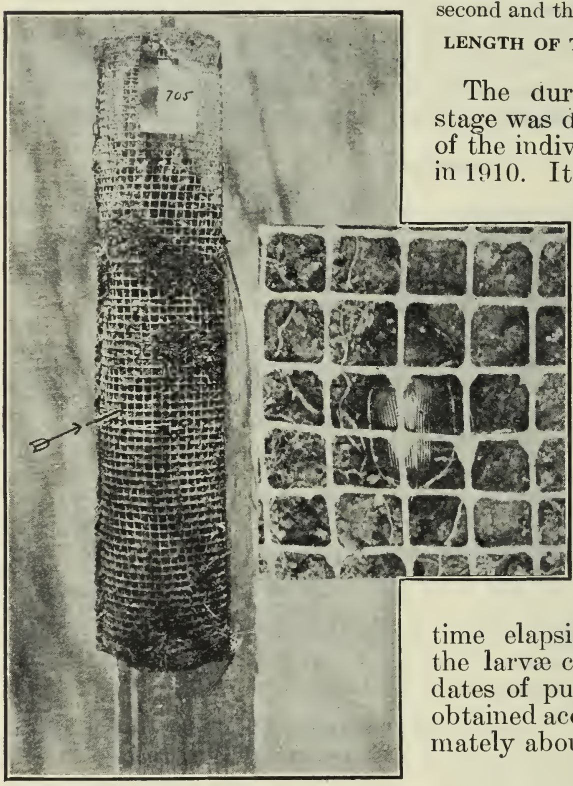

FIG. 5.—Individual hibernation cage that has been removed from the earth. Arrow shows where a Calosoma beetle hibernated; enlargement shows the beetle in the cage. (Burgess.)

LENGTH OF TIME TO COMPLETE LARVAL STAGES.

The duration of each larval stage was determined from a few of the individual records of larvæ in 1910. It was found that the first stage covered on an average 7 days, the second 5, and the third, to the date the larvæ ceased feeding, 14. As is shown in Table 8 the active growing period extends over about 28 days. The larvæ used in these experiments hatched June 9 and were practically full grown about July 5, or 26 days after hatching. The time elapsing between the dates the larvæ ceased feeding and the dates of pupation proper was not obtained accurately, but is approximately about 4 or 5 days.

FOOD CONSUMED BY LARVÆ.

Daily feeding records kept from the date of hatching to the date the larvæ ceased feeding and buried themselves for pupation were as shown in Table 8.

TABLE 8.—*Food eaten by larvæ of Calosoma wilcoxi, 1910.*

No.	Date hatched.	Date ceased feeding.	Sixth-stage caterpillars.		Total.
			Malacosoma americana.	*Porthetria dispar.*	
2778-D	June 9	July 12	3	7	10
2778-E	...do.....	2	7	9	16
2778-F	...do.....	8	2	13	15
2778-G	...do.....	4	3	16	19
2778-H	...do.....	1	8	9	17
2778-J	...do.....	12	8	11	19

Only one of the larvæ in Table 8 lived to pupate, namely, 2778–H. One escaped and the others died after they had become full grown.

The active feeding period of the larvæ was from 22 to 33 days, or an average of 28. The average number of full-grown caterpillars required for the completion of their larval stages was 16, and according to the data obtained they have approximately the same capacity as those of *inquisitor*.

HABITS OF LARVA.

Owing to lack of material no experiments, such as were conducted with *C. calidum*, *C. chinense*, and others have been tried to ascertain whether the larvæ of this species are terrestrial or arboreal in their habits of seeking prey.

THE PUPA.

One female pupa measured 16.5 mm. long and 7.5 mm. wide. No male pupæ were measured.

The one incomplete pupal record secured was from a larva which hatched June 9, 1910, and ceased feeding July 1. On July 14 the pupa was found in a cavity at the bottom of the jar, where it had probably remained eight or nine days, and would have issued in from three to five days more. This pupa was preserved in alcohol, so no adult was secured.

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Page 47. Short description with notes on occurrence.

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CALOSOMA FRIGIDUM Kirby.

ORIGINAL DESCRIPTION.

Frigid Calosoma, black underneath with greenish sides; elytra furrowed with the furrows punctured; interstices of the furrows elevated with transverse lines impressed, and a triple series of bilobed obscurely gilded punctiform impressions; margin greenish; posterior angles of the prothorax depressed. Length of the body 9½ lines. Taken in Drummond's Island, Canada, by Dr. Bigsby.

Not unlike *C. calidum*, but longer in proportion and more depressed. Body black, not glossy above. Head not confluently punctured and wrinkled; mandibles obliquely but less densely wrinkled, and frontal impressions longer than in *C. calidum;* prothorax scarcely wider than the head, posterior angles bent downward; elytra scarcely at all bronzed, lateral margin obscurely green, with the same number of elevated lines as in *C. calidum* but in the furrows formed by them is a series of punctures, and the transverse lines are less conspicuous; there is a triple series of punctiform impressions, but they are bilobed, smaller, and the gilding is greenish and less conspicuous; they are also less numerous, there being only seven or eight in the series next the suture, eight or nine in the intermediate one, and three only towards the apex in the external one; at the base there is also a pair on each side; the sides of the body underneath are greenish, punctured and wrinkled.

EARLY RECORDS OF THE SPECIES.

The species was first described by Kirby in 1837. Very little further attention was given it until 1848 and 1863, when LeConte included it in his "Descriptive Catalogue and Notes on the Species of Calosoma Inhabiting the United States." This species, like many others of its congeners, often attracts the attention of collectors and is present in most general collections. The senior writer, in 1896, was the first investigator to rear the species successfully through all its stages in confinement, and a continuation of the same work was attempted by himself and the junior writer in 1909 with a fair measure of success.

DISTRIBUTION.

This species occurs in Connecticut, Georgia, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Minnesota, Nebraska, New Hampshire, New York, Pennsylvania, Texas, and Wisconsin. It also occurs in Ontario and Quebec, Canada. Undoubtedly this species has a greater range than that above mentioned but it is more common in the northern part of the United States and in Canada.

COLLECTIONS AND SHIPMENTS.

From 1909 to 1912 adults and larvæ of this species were collected in the field and brought to the laboratory alive for biologic study.

In 1909 two males and two females were collected near Boston about April 15. Mr. R. Wooldridge stated that he saw three adults on June 18, feeding upon caterpillars of *P. dispar* in Wellesley, Mass.

On July 31 Messrs. Fiske and Burgess, while in Tamworth, Sandwich, and North Conway, N. H., investigating the natural enemies of *Heterocampa guttivitta*, found upwards of 100 beetles in a small infested area, and in one square yard of leaf mold collected 12 second and third stage larvæ of *frigidum*. The latter were fed and reared to maturity at the laboratory.

In 1910, 11 males, 7 females, and 2 larvæ were received, some of which were forwarded by Messrs. P. J. Parrott and H. E. Hodgkiss of Geneva, N. Y. Mr. Parrott collected these beetles at Geneva, Gates, and Seneca Castle, where they were found feeding upon cutworms (*Xylina* sp.). One specimen was taken while feeding upon caterpillars of *Euproctis chrysorrhœa* at Cape Elizabeth, Me.

In the season of 1912, 71 males and 38 females were collected and forwarded to the laboratory between June 1 and June 30. During these years many specimens were seen in the field but were not collected. The adults were frequently taken running up and down the trunks of trees.

HABITS OF ADULTS.

In order to check up the field observations on the climbing habits of this species an experiment was tried with a pair of adults using the apparatus shown in Plate III. The beetles climbed to the top of the tree immediately and with considerable speed. They climbed over the tree at will and were not once seen to fall during the few hours they were left in the experiment. Adults of this species have frequently been reported as fairly common in certain localities in the gipsy-moth infested area, especially under burlaps where they were doing appreciable good in feeding upon the caterpillars. The senior writer [1] found them common in localities in New Hampshire in 1909, where they were observed climbing the trees and feeding freely upon larvæ of *Heterocampa guttivitta.*

All indications point to the fact that the adults of this species find most of their prey on the trees, but the larvæ have very different habits as is pointed out in another part of this paper.

FOOD CONSUMED BY ADULTS.

Feeding records of adults were conducted through 1909, 1910, and 1911, but each year with different pairs, as in all the cases except one the beetles died before a second year's notes could be secured. Caterpillars of *Malacosoma americana* and *Porthetria dispar* were offered for food and the beetles attacked them voraciously. Some of the beetles were collected in eastern Massachusetts and others were reared at the laboratory. The records for 1909 and 1910 are contained in Table 9.

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[1] Burgess, A. F., Notes on *Calosoma frigidum* Kirby, a native beneficial insect. *In* Jour. Econ. Ent., v. 3, no. 2, p. 217-222 (p. 218), 1910.

TABLE 9.—*Feeding records of four pairs of Calosoma frigidum, 1909 and 1910.*

Pair No. and year.	Feeding record started.	Ceased feeding.	Sixth-stage caterpillars.		
			Malacosoma americana.	*Porthetria dispar.*	Total.
2731 (1909)	June 20	Aug. 20	77	153	230
4832 (1910)	2	July 12	92	100	192
4837 (1910)	4	13	35	20	55
4838 (1910)	4	27	51	57	108
Average, 146.					

Some of these beetles died and others entered hibernation at the end of the season.

Pair No. 2731 were collected in eastern Massachusetts during June, 1909, and reproduced in the jar that year. Thirty-seven fertile eggs were deposited by the female—a reason for the large amount of food eaten. None of the other females, all of which were pupæ of the fall of 1909, reproduced, consequently less food was required.

The records in no case were started as soon as the beetles emerged from hibernation, as some were collected in the field and the young stock that emerged in cages were retained until mates could be secured from the field. Unfortunately, record No. 4832, which promised to reach as high a limit as No. 2731, was discontinued a short time before the beetles ceased feeding normally. The beetles consumed from 55 to 230 full-grown caterpillars of *M. americana* and *P. dispar*, or an average of 146 to each pair. This average, without doubt, would have reached approximately 200 caterpillars had all the records been continued through the whole season, and if a larger percentage of the females had been more than one year old.

The beetles referred to in Table 9 emerged from hibernation between May 20 and June 9 and fed as late as August 20, but most of them ceased activity during the latter part of July. The active feeding period, therefore, extends over two to three months.

REPRODUCTION.

Two pairs of beetles confined in jars in 1909 were kept under observation for reproduction. One pair produced 37 eggs between June 21 and June 30. They were seen in copulation on June 24, 27, and 29, and died August 30 and 31 of that year, after having consumed 230 full-grown caterpillars of *Malacosoma americana* and *Porthetria dispar*.

In 1910 six pairs were confined in jars but only one pair reproduced. The female deposited eggs June 28 and 29, but only two hatched. In these experiments were one male and four females that were reared at the laboratory in 1909, and one of the females, which was paired with a male collected during the spring, deposited eggs.

One pair of the beetles (pupæ of the summer of 1909) lived until July 6, 1911, but did not reproduce in 1910 or 1911, nor were they seen in copulation either year.

During the year 1911 five pairs of beetles were under observation for reproduction. None of these were seen in copulation and only one of the five females reproduced. This was one of those collected during the spring and it deposited 12 fertile eggs.

One pair of beetles collected June 1 and 7, 1912, was placed immediately in a jar for rearing records. The female began oviposition June 8 and continued until June 23. One hundred and thirty fertile eggs were deposited and the female died July 2.

Thirteen pairs of beetles were confined in jars at the laboratory during 1909, 1910, and 1911, and only three pairs reproduced. Fifty-one fertile eggs was the total number secured, or an average of 17 to each female that deposited. In 1896[1] the senior author kept one female in confinement that produced 186 fertile eggs in one season. It is probable that most of the beetles collected during the spring and confined at the laboratory were young stock. It has been demonstrated and published in Bulletin 101 of the Bureau of Entomology that *Calosoma sycophanta* reproduces very sparingly during the first year, and the same is evidently true of *C. frigidum.* From four first-year females of the latter species in confinement during 1910 only two fertile eggs were secured.

LONGEVITY.

One pair of adults were collected in eastern Massachusetts about June 15, 1909. The male died September 2, 1910, and the female some time later during the same hibernation period. Another male collected in the spring of 1910 lived until June 21, 1911. The latter male was paired in a jar with a young female which was a pupa of the summer of 1909. The young female lived just one year in the adult stage. Another pair of beetles were pupæ of the summer of 1909. The male died during the hibernation of 1910–11, but the female lived until July 6, 1911. None of the beetles cited in the above instances reproduced while in captivity.

Those beetles that were collected in the field during the spring were probably pupæ the previous summer. On this basis the first pair of beetles cited lived one or two months over two years. The one which lived longest of any reared at the laboratory was a female, which remained alive for about two years. The available records do not show that this species lives longer than two years, but it is probable that it lives at least three years in the field.

HIBERNATION.

From the small collection of larvæ brought from New Hampshire August 1, 1909, five adults were reared. The larvæ ceased feeding between August 9 and 13 and then burrowed into the earth in the cages, where they constructed cavities for pupation. Four of the cavities formed were from 1 to 2½ inches below the surface, while one specimen was found 6 inches below. One female emerged May 20, 1910, three females May 26, and one male was dug up June 4. Two other pairs entered hibernation July 18 and 27, 1910, respectively. One female lived to emerge June 1, 1911, and one male was dug up June 7. They hibernated ¾ to 2 inches below the surface.

The average date that old beetles entered hibernation in the summer of 1910 was July 29, but young adults, which do not breed, may enter at a much earlier date. The notes also show that emergence took place in eastern Massachusetts from May 20 to June 7, and that the average depth at which the beetles hibernated was 2 inches.

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[1] Burgess, A. F. Notes on certain Coleoptera known to attack the gipsy moth. *In* 44th Ann. Rpt. Mass. State Bd. Agr. f. 1896, p. 412–431 (p. 419), pl. 3–5.

EXPORTATIONS.

June 17, 1912, 10 males and 10 females were packed with damp sphagnum moss singly in pill boxes, which were inclosed in a larger box and forwarded by mail to Mr. E. M. Ehrhorn, superintendent of entomology, in the Hawaiian Islands. The adults were fresh specimens, collected in the field just previous to the date of shipment. Mr. Ehrhorn wrote that only two males and three females arrived alive, but that those were very active. It was rather difficult to explain the reason for the death of so many individuals, as the moss in the boxes was still damp on receipt.

Cutworms had been reported as numerous and destructive in the islands by Mr. Ehrhorn, and it was thought desirable to attempt to introduce this species and *C. calidum* to prey upon these noxious pests.

THE EGG.

Fourteen fresh eggs gave the following average measurements: Length, 4 mm.; width, 1.7 mm. They are yellowish-white, somewhat elliptical in form, and taper slightly toward one end.

The eggs are deposited singly in the earth and hatch in from 4 to 10 days, depending mainly upon the temperature. Two hundred and sixteen eggs deposited in 1912 by several females between June 8 and 19 hatched, on an average, in about six days.

DESCRIPTION OF LARVA.

The following description of the larval stages was made in 1896 by the senior author:[1]

First larval stage.—At the time of hatching the young larva is of the same color as the egg, but gradually grows darker, until in about 10 hours it is of a deep shining brown. After remaining in the cavity occupied by the egg for about twenty-four hours, the larva comes to the surface of the ground in search of food. At this time the length is 8 mm., including the caudal appendages, which measure 1 mm.; the width at the middle of the first thoracic segment is 1.7 mm., from which point the body tapers gradually to the last segment. The head is large in proportion to the body, longer than wide, somewhat flattened, and truncate behind. The clypeus is separated from the epicranium by a well-defined suture, which extends to the base of the antennæ, dividing the raised portions from which they arise. The front edge of the clypeus is emarginate, and bears a prominent hair at each anterior angle. There are also three pairs of hairs situated on the forward part of the clypeus and two pairs directly between the eyes, one pair being on the clypeus and one on the epicranium. Antennæ setaceous, four jointed and ferruginous. Eyes conspicuous, and situated in groups of six each, on slight elevations just behind the antennæ. The mandibles are dark brown in color, long, simple, stout at base, but quite pointed at the tip, the left mandible often folded over the right. The maxillæ and labium are small, ferruginous and provided with well-developed palpi. Prothorax large, as long as the meso- and meta-thorax, slightly contracted and rounded posteriorly. Mesothorax slightly rounded posteriorly; metathorax truncate. Lateral edges of the body segments slightly produced. Dorsal line prominent on all the segments except the last. On the dorsum of each thoracic segment there are ten short hairs, one on the anterior part of each lateral margin, one at each angle of the segment and one on each side of the dorsal line at the anterior and posterior margins. Abdominal segments, nine in number, with the exception of the last, truncate behind, the last segment

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[1] Burgess, A. F. Notes on certain Coleoptera known to attack the gipsy moth. *In* 44th Ann. Rpt. Mass. State Bd. Agr. f. 1896, p. 412–431, pl. 3–5.

being rounded posteriorly and bearing a pair of caudal appendages. Each segment except the last bears six hairs, one on each lateral margin and two on each side of the dorsal line at the posterior margin. The last abdominal segment bears a pair of hairs on each lateral margin, but none on the dorsum. The caudal appendages are entire, although probably jointed at the base, and bear numerous hairs. The spiracles are situated just below the dorsal plates. The ventral portion of the body is of a yellowish white except the portions which are strengthened by chitinous plates. These are of the same color as the dorsal part of the body. Legs well-developed, provided with stout spines which are especially prominent at the joints, the tarsi bearing two claws. The last body segment bears on the posterior ventral portion an appendage which serves as a proleg and aids in locomotion. The larva remains in this stage about four days. Molting is accomplished by a splitting of the thoracic plates along the dorsal line; the head, mouth parts and legs are then withdrawn and the exuviæ forced back over the posterior end of the body. The newly molted larva is of a pale straw color.

Second stage.—Length, 15 mm.; width, 3 mm. Form somewhat stouter than in the preceding stage. Head relatively smaller, flattened, as wide as long; eyes less prominent. Clypeus deeply emarginate in front and feebly incised at the middle. Antennæ and mouth parts relatively the same as in the last stage; the body, however, is of a somewhat paler brown color. All the body segments except the last are truncate behind, and bear a well-defined dorsal line. The first thoracic segment is broadest posteriorly and gradually narrows toward the head, but is not quite as wide as the two succeeding segments. The hairs are arranged the same as in the first stage, except that two pairs of hairs arise on the lateral edges of each segment up to the last, which bears only one pair. The caudal appendages are entire but not quite as prominent as in the previous stage, and the legs are a little more slender. The time spent in this stage varies from four to eleven days.

Third stage.—After molting the larva measures 22 mm. in length and 4 mm. in width, and is of a light mahogany-brown color, which soon changes to a dark seal brown. The mandibles are stout, and bear a prominent carina. The clypeus is deeply bilobed in front, the hinder border separated from the epicranium by a somewhat indistinct suture. Prothorax narrowed in front and much wider behind. Caudal appendages each provided with a blunt spine, which is thickened at the base and arises from the dorsal surface. When full grown the larva is very stout, and measures 32 mm. in length, and 6 mm. in width. A detailed description of the full-grown larva follows:

The head is of medium size, slightly flattened and of the same color as the body. Clypeus somewhat shield shaped. A faint line separates the clypeus from the epicranium and reaches to the base of the mandibles, but does not divide the raised portions which bear the antennæ. Front edge of clypeus strongly bilobed, each anterior angle bearing a prominent spine; top of the clypeus slightly hollowed toward the dorsal line. The spines are the same in number and arrangement as in the previous stages. Eyes near base of antennæ, not prominent. The antennæ are setaceous, short, four-jointed, and arise from an elevation at the base of the mandibles. First joint short, cylindrical and naked; second joint nearly twice as long, slightly clavate and bearing a short hair near the middle of the outer margin; third joint a little shorter than the second, somewhat clavate and having one anterior angle slightly produced, and bearing three spines, which arise near the outer angles; last joint as long as the first, nearly cylindrical and bearing three spines at the apex. Mandibles large, stout at base, with a prominent dorsal carina. A strong, simple, blunt tooth arises near the base. The mandible gradually tapers from the outermost insertion of this tooth to a somewhat chisel-shaped point. The maxillæ are small, ferruginous in color, and are densely covered with hairs and spines. They bear four-jointed, naked palpi, which are nearly as long as the antennæ. The three inner segments of the maxillary palpus are short, stout, truncate, and of nearly equal length; the terminal joint is slightly longer than the two preceding joints, oblong ovate in form and truncate at the tip. The galea or inner lobe is naked, two-jointed and as long as the three basal joints of the palpus. Lacinia prominent and bearing a spine at its apex. Labium small, somewhat halberd shaped, with numerous spines arranged in an oval row on the inner side. Palpi two-jointed; outer joint the longer and truncate at tip.

The dorsal thoracic plates are large, and nearly cover the lateral thoracic walls, while the dorsal abdominal plates, with the exception of the last, are smaller, and allow the lateral walls of the abdomen to protrude. Dorsal line not prominent. Each abdominal plate except the last bears, near the posterior margin, a very feeble transverse carina. Spines are arranged as in the preceding stage. The last segment is relatively small, nearly truncate behind; the caudal appendages of moderate length, and each bears on the upper surface a large, blunt, hornlike protuberance, which is terminated with a bristle. Numerous other hairs occur on these caudal appendages. The ventral portion of the body is yellowish white except the parts which are strengthened by chitinous plates.

Spiracles seal brown, nine on each side, borne in shallow depressions just below the lateral edges of the dorsal plate, on the mesothorax and on each abdominal segment except the last. Those on the abdominal segments are small and circular, while the thoracic spiracles are decidedly larger and elliptical in outline. Legs small, very muscular and spiny. Coxæ very stout, dark brown; trochanters, femora and tibiæ slender, reddish brown; tarsi of same color, one jointed and bearing two simple claws. The anal proleg is slender, tapering and bears a number of short spines. This appendage serves the double function of acting as an organ of locomotion and also containing the cavity into which the rectum discharges. General color of under surface sordid white, varying to light gray, variously marked with light seal-brown patches. Head and anterior part of prothorax seal brown. Two lateral rows of elongated markings of similar color extend along the body beneath the spiracles. The upper row terminates on the penultimate segment, the lower row on the last segment.

The markings forming the upper row are single and entire on the first two thoracic segments; on the metathorax there are two spots, the anterior being the smaller. On the abdominal segments the markings are somewhat circular, two to each segment, a large orbicular marking being followed posteriorly by a smaller one of similar shape. The markings composing the lower row are in general elliptical, and occur singly on the segments stated. On both the meso- and meta-thorax there is a single small brown spot on the median line. In a corresponding position on each of the following segments except the last two, and near the anterior margin, there is a large elliptical, transverse, seal-brown spot. Posterior to this marking on each of the segments mentioned there is a transverse row of four small spots of similar color. On the last two segments the median spot is quite large and somewhat pentagonal in outline. The transverse row of small spots occurring on the preceding segments is here absent.

The full-grown specimen measured and referred to in the foregoing description was probably abnormally large, as those measured recently do not exceed 30 mm. in length. Larvæ in this stage have a reddish-brown patch at the base of the caudal appendages.

THE PUPA.

Following is a description of the pupa:

Length, 18 mm.; width at first abdominal segment, 6.4 mm. Oblong, somewhat elliptical and flattened. General color of the body pale amber. Head medium, somewhat flattened in front and strongly depressed beneath the thoracic segments. Eyes prominent, seal brown in color. Antennæ and mouth parts free, translucent. Prothorax broader than long, considerably narrowed behind; mesothorax emarginate in front and two-thirds as long as the metathorax; all separated by well-defined sutures. Wing covers translucent and extending beyond the third abdominal segment. Abdominal segments nine in number, the sides of the body protruding beyond the dorsal portions. The lateral edges of abdominal segments 2 to 6 produced to a blunt point, within which is a slight depression. Penultimate segment slightly depressed; last segment greatly depressed beneath the body, and bearing on the posterior margin a pair of small anal stylets. Each of the first five abdominal segments bears a narrow brush of erect brown hairs, which extends two-thirds of the distance across the segment. The nine pairs of spiracles are light chestnut brown, and are situated in the same relative position as those of the larva; they are larger, however, and elliptical in outline, those on the metathorax being the largest. Legs free, translucent, and nearly surrounded by the wing covers.

Although a few adults were reared from larvæ in 1909, no specific data were secured on the exact time passed in the pupal stage. August 2 one full-grown third-stage larva was collected in New Hampshire and fed until August 9. August 13 it was transferred to a small fly-screen cage, which was set in the ground, and allowed to bury up for pupation. October 4 the cage was removed and a young living female was found in a cavity 6 inches below the surface. The female was replaced in the same cage in a cavity 2 inches below the surface and reset in the ground. May 26, 1910, the female emerged from the latter cavity.

Other full-grown larvæ were placed in similar cages about the same time and were not disturbed, but allowed to emerge normally the following spring. One specimen was unearthed in the fall to make sure that this species does not hibernate in the larval or pupal stages. None of the adults reared in 1909 emerged from its cavity as soon as transformation from the pupa took place, as did *C. calidum.* The time spent in this stage varies, being apparently from 10 to 14 days.

TIME REQUIRED TO COMPLETE LARVAL STAGES.

Data secured from larvæ in 1909 showed that the first stage covers a period of from 2 to 5 days or an average of 4; the second an average of 5, and the third 11. The total number of days the larvæ are active and feed is 20, after which time they burrow into the earth and form the pupal chamber. The time required for this is practically the same as with other species of the genus studied.

FOOD CONSUMED BY LARVÆ.

Mention has previously been made concerning the feeding of the larvæ upon the larvæ and pupæ of *H. guttivitta* in New Hampshire. Some larvæ were brought in from the field in second and third stages and fed to maturity on caterpillars of *Porthetria dispar.* A few others that hatched from eggs deposited in breeding jars were fed until they reached the third stage, when all died, and combinations were thus compiled from these.

The data obtained from feeding records of these larvæ are given in Table 10.

TABLE 10.—*Food eaten by larvæ of Calosoma frigidum, 1909.*

No. of larva.	*Malacosoma americana and Porthetria dispar* fourth and sixth stage caterpillars eaten during first larval stage.	*Porthetria dispar.* Sixth-stage caterpillars eaten during second larval stage.	*Porthetria dispar.* Sixth-stage caterpillars eaten during third larval stage.	Total.
2731-A	2	6	....	....
2765-A	....	....	9	17
2731-E	3	....	....	....
2765-B	....	4	13	20
2731-H	3	4	....	....
2765-E	....	....	11	18

The average number of large-sized caterpillars, mostly sixth-stage *Porthetria dispar,* consumed by a single larva from hatching to maturity was 19, or approximately the same number as was destroyed by larvæ of *C. wilcoxi* or *C. inquisitor.* Had caterpillars of *Heterocampa guttivitta,* which are much smaller, been used, the number destroyed would undoubtedly have reached 25 or 30. June 23 and 28 were the dates of hatching of some of the larvæ, and they continued their activity in and out of the earth in jars for about 20 days.

Two larvæ that hatched June 24, 1912, were fed almost to maturity and died July 10 and 11, respectively. They were supplied chiefly with pupæ of *Porthetria dispar*, but at the beginning caterpillars of *Malacosoma americana* were offered. Six caterpillars and 8 pupæ were consumed by the first larva and 4 caterpillars and 10 pupæ by the second.

Data secured in New Hampshire in 1909 and 1910 on the feeding habits of the larvæ upon *Heterocampa guttivitta* indicated that the pupal stage of the latter species furnished the most victims of attack. The larvæ of *frigidum* were approaching maturity at the time most of the caterpillars of *Heterocampa guttivitta* had entered the pupal stage in cells under leaf mold. In these cavities the larvæ of *frigidum* devoured large numbers of them.

HABITS OF THE LARVÆ.

June 21, 1911, five larvæ, which hatched June 20, and some of which had fed a little, were tested as to their ability to climb. (Pl. III.) Three of them, when placed upon the bark of the tree, clung to it for a short interval, then crawled into crevices and remained there. The other two repeatedly fell from the bark as soon as placed upon it. At 9 a. m., when the experiment was started, caterpillars were left in a cage at the top of the tree for food. At noon all the larvæ were on the ground, running around the circle and attempting to climb up the tin in an endeavor to escape. On the morning of June 22 four of the larvæ were found in the earth in the circle, but there was no evidence of any having entered the food cage during the night. Two of the larvæ were again placed upon the bark of the tree, but fell each time without climbing. On June 23 there was no evidence that the larvæ had entered the food cage since the preceding day. June 24 one first-stage larva was again placed upon the tree, but it showed very little inclination to climb, each time hiding under the loose scales of the bark and immediately falling when forced to crawl from under them. June 25 only two first-stage larvæ could be found, after examination of all the earth, and one of these was very weak from approaching starvation. Neither had entered the food cage over night. June 26 one of the larvæ that was found in the circle the preceding day was dead and the other was almost dead. June 27 one other first-stage larva was found in the earth at the base of the tree, having been overlooked in the search of the two previous days. It was also very weak and was removed and placed in a jar of earth and fed, but died later, presumably from the prolonged starvation.

Two were lost during the experiment and it is quite probable that they were devoured by their mates, for the latter lived about six days without other food. A further test was made with larvæ of this species in all stages between June 26 and July 6, 1912. They were left inside the circle during this time with food in the cage at the top of the tree but they did not climb there to secure it. They were removed and fed when starvation seemed imminent, or lepidopterous pupæ were left on the surface of the earth in the circle for a brief period. They were many times placed upon the bark of the tree but did not crawl in any case more than 6 inches before falling. Three inches upward was the best progress noted.

The data at hand is rather conclusive that these larvæ seemed to search for their food in, on, or near the ground. Starvation resulted if the food supply was elsewhere.

Starvation, and to a slight extent cannibalism, among the larvæ is, in the writers' opinion, almost totally responsible for the nonincrease of the species in the areas infested by the gipsy moth and brown-tail moth. From the data at hand it also seems probable that *frigidum* does not reproduce as abundantly as some of the other species investgated.

In the gipsy moth infested area the beetle larvæ occasionally find stray caterpillars crawling upon the ground, but these, on the whole, are scarce except in cases where woodland is being stripped and caterpillars are migrating in search of food. The writers have not heard or noted *C. frigidum* as numerous in the area above mentioned as they were in the White Mountain region of New Hampshire in 1909,[1] when *Heterocampa guttivitta* defoliated large areas of beech, maple, and other woodland growth and when 87 per cent of the pupæ were destroyed by larvæ of *frigidum* in a single year. The caterpillars of *Heterocampa guttivitta* furnish more food for *frigidum* larvæ than those of *Porthetria dispar* and *Euproctis chrysorrhœa*, because the former usually fall or descend to the ground during their feeding stages. Hence, the species, as a whole, fares much better in a locality where *Heterocampa guttivitta* or other lepidopterous insects that pupate on the ground are present than where caterpillars or pupæ are present that remain in the trees. This, it is believed, explains why *C. frigidum* has not increased rapidly and become an important factor in destroying the gipsy and brown-tail moths.

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Notes on the abundance of the species in the White Mountains, N. H., where there were outbreaks of *Heterocampa guttivitta*. It was found on August 21–25, 1909, that an average of 54 per cent of the pupæ had been destroyed by *frigidum* larvæ, and they were still present and feeding.

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Contains notes and tables to the effect that 87 per cent of the *Heterocampa guttivitta* pupæ in localities of the White Mountain region were destroyed by *frigidum* larvæ during August, 1909, and that 3.66 per cent died from the attack of parasites or from other causes.

CALOSOMA INQUISITOR (L.).

ORIGINAL DESCRIPTION.

[Translation.]

Elytra striate, greenish-bronze: punctures in triple row.

Roland act. Stockls. 1750, p. 292, t. 7, f. 3. Carabus, winged, greenish-coppery, punctate and striate concavely, feet and antennae black.

Habitat in trees of Europe, living on larvæ of *Papilio* and *Phalaenalis*.

Elytra golden, with green margin. Thorax very short.

EARLY RECORDS OF THE SPECIES.

This very interesting species was described by Linnaeus in 1758 as *Carabus inquisitor*. Since that time it has attracted the attention of many prominent European entomologists, judging from the many short and unique accounts written about it. Linnæus, in 1758 and 1761, gave its habitat as Europe, destroying larvæ of Papilio and Phalænalis in trees. Paykull, in 1790, gave a lengthy and comprehensive description, giving the habitat as forests and gardens. Panzer, in J. G. Voet's "Beschreibungen und Abbildungen Hartschaaligter Insekten," Col. Tab. 38, fig. 39, 1793, presents a life-size colored figure of the adult. Description and references to the species are made in 1795 by Olivier, who says that "* * * it is found ordinarily on trees, principally oaks, where it catches different insects on which it is nourished."

Geoffroy, in 1799, lists what is undoubtedly this species under Buprestis; and Fabricius, in 1801, the year that Friedrich Weber established the genus Calosoma, placed this species under the latter genus. Thomas Marsham, in 1802, lists this species as *Buprestis sycophanta minor*, and P. A. Latreille, in 1804, included it under Calosoma, where it has remained until the present time. Latreille reported it as being found about Paris but less commonly than *C. sycophanta* L.

Dejean, in 1826, reported the species common in Germany and northern Europe but more rare in France. J. T. Dawson, in 1854, stated that the species occurred on oaks in different localities in England and Ireland. The following reference is quoted from J.T. Harris, published in 1865–66.[1]

> Occurrence of *Calosoma inquisitor* near Burton-on-Trent. In a woodland near here I was fortunate enough, early in June last, to take about 30 specimens of this insect and could have taken more. I found several in the sunshine and also, just at dark, moving about freely on the stems of the oak trees but did not observe many during the daytime high up on the branches, as described by Mr. F. Plant in "The Zoologist" some years back. J. T. Harris, 31 Lichfield St., Burton-on-Trent, July 3, 1865.

The larva of this species was first described in 1867 by J. C. Schiodte in his remarkable work, "De Metamorphosi Eleutheratorum Observationes."

C. Houlbert and E. Monnot, in 1905, published on the species, describing the adult and giving a short description of the larva. They named many localities in central France where the species is known to occur.

IMPORTATIONS.

All importations of this species in 1906 were forwarded by Miss Marie Ruhl, Zurich, Switzerland. The exact localities in Europe where collections were made could not be ascertained, as the specimens were forwarded to her, then repacked and shipped to the gipsy moth parasite laboratory.

TABLE 11.—*Importations of Calosoma inquisitor from 1906 to 1910.*

Year.	Number living.	Received dead.
1906	280	170
1907		
1908	1	
1909	91	4
1910	143	36
Total	515	210

The mortality during transit was much greater in 1906 than in later years. A change in methods of packing and shipping gave better results. Most of the living specimens were liberated very soon after receipt but a few were kept for cage and jar records in order that closer observations might be made.

HABITS OF ADULTS.

Experiments showed that these beetles are very agile on the trees and that they prefer running up and down the trees rather than remaining on the ground. Their favorite hiding place is in the crotches of trees. These observations bear out those of J. T. Harris in 1864–65, which are quoted in another part of this paper. This species has habits similar to *C. frigidum* in all stages. The adults of both species intuitively search for their prey in trees, finding caterpillars that feed upon the foliage.

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[1] See Bibliography, p. 62.

Undoubtedly adults of this species fly, but this has not been positively proved. A few attempts to induce them to do so were made in 1911, by tossing specimens in the air, but all the beetles dropped heavily to the ground without spreading their wings. This same sort of treatment of *sycophanta* by the junior author resulted in the escape of a few specimens, these skimming gracefully out of sight.

FOOD CONSUMED BY ADULTS.

The capacity for consumption of food by this species is much less than that of the larger species, such as *scrutator* and *sycophanta*. The feeding records of four pairs are given in Table 12.

TABLE 12.—*Feeding records of 4 pairs of Calosoma inquisitor, 1910.*

Pair No.	Emerged from hibernation.	Ceased feeding.	Fifth and sixth stage caterpillars.			
			Noctua clandestina.	*Malacosoma americana.*	*Porthetria dispar.*	Total.
2706	May 24	July 7	....	112	8	120
2720	20, 24	19	....	68	13	81
2721[1]	17	19	10	124	9	143
2722	24	13	....	61	6	67

[1] Female reproduced in June.

The average number of large caterpillars consumed by each pair of beetles in 1909 and 1911 was 50 per year, but this record is too low, as the experiments were not started until about June 10.

The records secured in 1910 (Table 12) were normal and were kept consecutively from the date of emergence in the spring to the date the beetles entered hibernation. Each pair destroyed on an average 103 large caterpillars of *Malacosoma americana* or *Porthetria dispar.*

REPRODUCTION.

The first living adults of this species were imported from Europe in 1906, but the few attempts made at rearing the species at that time were unsuccessful.

June 7, 1909, many living specimens were received, and several pairs were placed in battery jars for rearing and feeding records, but no eggs were deposited during that year. In 1910 one female out of 13, of which close records were kept, oviposited, and this female was received from Europe in 1909. Seventy-nine eggs were deposited between May 24 and June 10, 1910, which is the largest record for any female of this species in a single year.

One female of the importation of 1909 that did not reproduce that year or the following deposited 23 fertile eggs between June 1 and June 27, 1911, and died July 3. A few other females received in 1910 did not reproduce that year, but did so in 1911.

After reading these notes one can perhaps appreciate the many disappointments experienced in rearing predacious beetles. Frequently there was no reproduction from females for two successive years.

LONGEVITY OF ADULTS.

July 8, 1908, one female was received from Europe, and in the fall of that year was placed in a hibernation cage in the laboratory yard. There were no males to pair with this female until 1909. As soon as a shipment was received a mate was given her. The female lived to enter hibernation in the fall of 1910, but in the spring of 1911 no trace of her could be found in the cage. The adult mentioned was a larva in the summer of 1907 or earlier, and therefore lived at least three years in the adult stage. This female did not reproduce.

One pair of beetles, No. 2720, received from Europe on June 7, 1909, lived until July 3, 1911, when both died. At the time they died the weather was very hot, the temperature in the jars reaching 107° F. several times. The female produced 79 fertile eggs in 1910, but none in 1909 or 1911. These beetles must have been in their first year when received in 1909, thereby living two winters and three summers after reaching Massachusetts. Another female in the same shipment lived until July 5, 1911, and did not reproduce during three years. The original mate of this female, received at the same time, lived two winters and two summers to date of entering hibernation in 1910. Still another female with an interesting record was received from Europe on the same date as the preceding, and lived to enter hibernation in the late summer of 1911. The mates of this female died each summer, and although she was each time supplied with another she failed to reproduce. This female died in hibernation during the winter of 1911–12, having lived more than three years.

HIBERNATION OF ADULTS.

Close observations were made on a series of breeders in 1909, 1910, and 1911 to obtain the exact dates of their entering and emerging from hibernation. This varies in different years and with beetles of different ages, as will be shown by Table 13.

TABLE 13.—*Showing date of entering and emerging from hibernation of Calosoma iniquisitor during 1909, 1910, and 1911.*

No.	Sex.	Date entered, 1909.	Date emerged, 1910.	Depth of cavity, 1910.	Date entered, 1910.	Date emerged, 1911.	Depth of cavity, 1911.
				Inches.			*Inches.*
2706	Male....	June 28	May 24	1	July 7	(1)	(2)
	Female .	...do....	...do....	(3)	...do....	(4)	....
2720	Male....	June 24	May 20	(3)	July 19	May 15	1½
	Female .	...do....	May 24	1	...do....	...do....	2
2721	Male....	July 8	May 17	(3)	...do....	...do....	1
	Female .	...do....	...do....	(3)	...do....	...do....	1
2722	Male....	June 20	May 24	1	July 13	(4)	....
	Female .	...do....	...do....	1	...do....	June 5[6]	4
2723	Male....	June 25	June 16[5]	6	July 2	....	(3)
	Female .	...do....	...do[6]...	16	...do....	May 27	(3)

[1] Died in hibernation.
[2] On surface.
[3] Unknown.
[4] Missing.
[5] Dead.
[6] Alive; cages dug up before beetles emerged.

The date of entering hibernation in Table 13 is the time the beetles ceased feeding and made cavities in the bottom of the breeding jars. The beetles were transferred from these to hibernation cages as soon as possible, and in each case they were obliged to construct another cavity. One will note from the table that the beetles ceased feeding to enter hibernation earlier in 1909 than in 1910, the average date being June 27 in the former year, and July 12 in the latter. Only one of the females (No. 2723) lived to enter hibernation in the fall of 1911 and this one died before the following spring. All the original males and females in this series, except female No. 2706, which was received in 1908, were received from Europe in the spring of 1909. Some of the males died later but were replaced with males from more recent shipments. These beetles may have been collected in Europe in a locality where spring opens at an earlier date than in New England, and as a consequence their active feeding season was cut short in 1909. The records of 1910 appear more nearly normal. The writers suspect that female No. 2723, whose cage was dug up June 16, 1910, disclosing the beetle at a depth of 16 inches, might have remained dormant through that summer until the next spring had she not been disturbed at that time. The junior author discovered in 1911 that this habit is peculiar to a portion of *sycophanta*, which gives reason for suspicion that this and other species of the genus may have the same habit.

The depths of the cavities of this species range from 1 to 16 inches but most of them were found from 1 to 4 inches below the surface.

COLONIES.

Most of the beetles imported were liberated in suitable localities soon after receipt; a very few of this species were kept for study. In all, five separate colonies have been liberated since 1906. On June 20 of that year Mr. E. S. G. Titus and Mr. F. H. Mosher liberated 80 specimens in woodland which was badly infested by the gipsy moth in Lynnfield, Mass. On the same date another colony of 87 specimens was placed in the same town about a mile from the first liberation, and on July 7, 20 specimens were released a short distance from the point where the last-mentioned planting was made. These colonies were visited several times during the summer of 1906, but no beetles or larvæ were recovered. In 1908 a number of trees in the center of each of these colonies were burlapped and several examinations were made during the summer, but none of the beetles or their larvæ were found. Numerous examinations have been made since that time with similar results.

On June 15, 1909, 27 males and 45 females were released in badly infested woodland in Melrose, Mass., and although several careful examinations were made that year and in the years following the species has not been recovered. On June 26, 1911, nine second-stage larvæ of this species that had been reared at the laboratory were placed in a cultivated field in Saugus, Mass., where cutworms were abundant. At that time it was anticipated that more *inquisitor* larvæ could be added to this colony, but owing to a heavy mortality in the rearing jars it was impossible to do this. It was desired to see if it was not possible for this species, particularly the larvæ, to develop if liberated in surroundings where caterpillars which were terrestrial in habit were within easy reach. Although several examinations have been made, no living specimens of *inquisitor* have been recovered in this or in the other colonies that have been liberated. It is probable that the failure of the beetle larvæ to climb explains in part the inability of the species to become established in this country. It will be noted that no large colonies were liberated, and this may have made it more difficult for the species to propagate and develop. Apparently *inquisitor* is not as hardy a species as *sycophanta* or the species of Calosoma native to New England. At any rate the chances of it having become established in this country are very small.

THE EGG.

The egg is yellowish-white, elliptical, usually tapering toward one end. Twelve fresh eggs gave the following average measurements: Length, 4.3 mm.; width, 2.4 mm.

Seventy-nine eggs were deposited by one female between May 24 and June 10, 1911, and these required an average of 9.6 days to hatch. Seventy-one eggs were deposited by six females in 1911 between June 1 and June 27 and averaged 6⅕ days in the egg stage. The difference in time noted above was due to the temperature, as high temperature favors rapid hatching.

BRIEF DESCRIPTION OF LARVA.

First stage.—Color brownish-black above, ventral plates brownish-gray. Form slender. Average length of 12 specimens, 8.9 mm.; width, 2.3 mm. Caudal appendages of medium length, rather slender.

Second stage.—Color brown to dark brown above; ventral plates chestnut brown. More slender than first stage. Average length of 12 specimens, 12.6 mm.; width, 2.9 mm. Caudal appendages stouter but no longer than in first stage.

Third stage.—Body more robust than in previous stages. Average length of 12 specimens, 21 mm.; width, 4.5 mm. Posterior angles of anal segment acute and extending backward rather prominently. Caudal appendage stout, almost straight; dorsal protuberance prominent, erect, located about two-thirds distance from base to tip. Color same as in second stage. A reddish-brown patch at base of caudal appendages in second and third stages.

LENGTH OF TIME REQUIRED TO COMPLETE LARVAL STAGES.

Observations were made on 14 larvæ during the summer of 1910 to determine the length of time passed in each stage. The average for the first stage was 8.6, for the second 6.6, and for the third 8.7 days to the date the larvæ ceased feeding. Twenty-four days covered the active growing period of the larvæ. The time passed in the first stage may appear somewhat long as compared with records of other species, but the weather was cool during the first part of June and retarded the growth and activity of the larvæ.

FOOD CONSUMED BY LARVÆ.

Twenty-two feeding experiments with larvæ were started in individual jars during the summer of 1910 and from these 14 complete records were secured, as shown in Table 14.

TABLE 14.—*Food eaten by larvæ of Calosoma inquisitor, 1910.*

No.	Date hatched.	*Malacosoma americana* caterpillars eaten, fourth to sixth stages.	*Porthetria dispar* caterpillars eaten, fourth to sixth stages.	Total.	No.	Date hatched.	*Malacosoma americana* caterpillars eaten, fourth to sixth stages.	*Porthetria dispar* caterpillars eaten, fourth to sixth stages.	Total.
2721-A [1]	June 1	5	18	23	2721-M	June 3	5	16	21
2721-B	1	5	7	12	2721-P	4	4	8	12
2721-C	1	6	7	13	2721-Q	4	4	4	8
2721-E	1	2	10	12	2721-R	5	4	14	18
2721-F	3	8	6	14	2721-S	5	10	13	23
2721-G	3	7	7	14	2721-U	5	5	8	13
2721-I	3	7	19	26	2721-V [1]	6	8	9	17

[1] Full-grown larvæ died.

Twelve larvæ in Table 14 lived to pupate and two died when full grown. The average date that the larvæ hatched was June 4, and the average date they ceased feeding June 30, so that the active feeding and growing period extended over 26 days. The average number of fourth to sixth stage caterpillars of *Malacosoma americana* and *Porthetria dispar* caterpillars required by each larva to complete its growth was 16.

HABITS OF THE LARVÆ.

Several larvæ were tested as to their inclination and ability to climb trees in search of food. (Pl. III.)

June 9, 1911, three larvæ less than 24 hours old were placed on the surface of the earth within the tin circle. Two of the larvæ were repeatedly placed upon the bark of the tree, where they crawled for one or two minutes, in and out of the smallest crevices, and then fell to the ground. They did not climb as much as 2 inches either up or down the tree before falling.

The experiments were continued until June 30 with first and second stage larvæ and observations made once or twice each day. The larvæ in neither of the two stages were observed at any time attempting to climb on their own initiative. There was no evidence of their ever having entered the food cage during the continuation of the experiment. No third-stage larvæ were tested on account of lack of specimens.

This species in all stages has habits very similar to *C. frigidum*. The adults of the latter are commonly found upon trees whereas no reports have come to us of their larvæ having been taken in such situations. Some bibliographical references and notes made at the laboratory indicate that adults of *C. inquisitor* climb for their food while their larvæ search for it at or near the ground.

THE PUPA.

One female pupa measured 15 mm. in length and 7 mm. in width, and 2 females averaged 15.8 mm. in length and 7.3 mm. in width.

Out of 22 feeding records kept in 1910, 7 of the larvæ after they ceased feeding were obliging enough to make cavities for pupation at the bottom or side of the jars. This made it possible to make notes on their transformations without disturbing them. In some cases the prepupæ were removed from their cavities and placed upon the surface of the earth where their metamorphoses could be observed more easily. Table 15 gives an idea of the dates of the changes from larvæ to pupæ and the issuance of adults.

TABLE 15.—*Date of hatching and transformations of larvæ and pupæ of Calosoma inquisitor, 1910.*

No.	Date eggs hatched.	Date larvæ ceased feeding.	Date pupated.	Sex.	Date adults issued.	In pupal stage.
	1910.					*Days.*
2721-C	June 1	June 24	(1)	Female.	July 14	(1)
2721-E	1	27	(1)	Female.	19	(1)
2721-G [2]	3	30	July 3	Female.	12	9
2721-M	3	July 6	(1)	Female.	22	(1)
2721-P	4	June 29	July 3	Male	16	(1)
2721-R	5	...do	4	Female.	15	11
2721-U	5	June 28	8	Male	21	13

[1] Not known. [2] Pupated on surface of earth in jar.

In the foregoing records the date on which the larvæ ceased feeding and adults issued is given in each case. In three of the records the date the larvæ pupated was ascertained. Six days is the average time between the dates feeding ceased and pupation took place; hence if 6 days is added to the date on which feeding ceased in cases marked "not known" in Table 15, the date of pupation will be indicated. After averaging the records in the table in the above-mentioned manner it is found that 6 days are required for constructing a cavity and preparing for pupation and 12 days are spent in the pupal stage.

STARVATION EXPERIMENT CONDUCTED IN 1911.

May 27, 1911, a pair of beetles emerged from hibernation and were placed in a jar of earth without food to ascertain how long they would live. The female died June 8 and the male June 18. The former lived 12 and the latter 22 days without food after emerging from hibernation.

A male reared in 1910 emerged from hibernation May 25, 1911, and was placed in a jar without food. This specimen lived until June 2, or 8 days after emergence.

It is very evident that beetles less than 1 year old require food sooner than older specimens. The experiment indicates that *inquisitor* can not survive as long without food as its congener *sycophanta*, a detailed account of which is given in Bulletin 101 of the Bureau of Entomology.

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Page 414. Contains the original description of the species, under the genus Carabus; gives its habitat as Europe, states that it feeds upon larvæ of Papilio and Phalaenalis.

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Page 669, No. 11. Same as original description.

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Page 239. Short description giving habitat as Europe.

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1787. Fabricius, J. C. Mantissa Insectorum, t. 1, 348 p. (p. 197, no. 31).

1790. Paykull, G. von. Monographia Caraborum Sveciæ. 138 p.

Page 65, No. 39. Full description of the species with good notes as to its habitat. The author reports finding it in forests, but twice as abundant in the Carlbergian garden, under stones and decayed leaves toward the end of the month of May.

1792. Fabricius, J. C. Entomologia Systematica, t. 1, 538 p. Hafniæ.

Page 149. Short description with biographical references.

1793. Voet, J. E. Beschreibungen und Abbildungen hartschaaligter Insekten, Coleoptera, Linn., von G. W. F. Panzer. 5 pt., 48 pl.

Contains many references and a short description of the species, which is referred to as "Der Raupenjager" (The caterpillar hunter) (p. 86, no. 39, pl. 38, fig. 39).

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Short description comparing it with *Carabus vagans*, also list of references. The author reports that it is ordinarily found upon trees, mainly oaks, where it catches different insects upon which it is nourished.

1798. Paykull, G. von. Fauna Svecica, t. 1, 234 p.

Page 127. References and description with the same notes as to its habitat, cited in his Monographia Caraborum.

1799 GEOFFROY, E. L. Histoire Abrégée des Insectes, t. 1, 556 p., 10 pl. Paris.

Page 145, No. 6. The species is here described under the genus Buprestis. All previous references list it under Carabus.

1801. FABRICIUS, J. C. Systema Eleutheratorum, t. 1, 506 p. Kiel.

Page 212, No. 7. The species is here placed in the genus Calosoma for the first time after the establishment of the new genus by Weber.

1802. MARSHAM, T. Entomologia Britannica, t. 1, 547 p.

Page 448, No. 40. Described and listed as *Buprestis sycophanta minor.* "Habitat in forests, army of insects running over green twigs by night."

1804. LATREILLE, P. A. Histoire Naturelle Générale et Particulière des Crustacés et des Insectes, t. 8, 411 p.

Page 299. This author again places the species in the genus Calosoma where it has remained since that date. "It is found in the vicinity of Paris, but is less common than *Calosoma sycophanta.*"

1810. GYLLENHAL, Leonardo. Insecta Svecica, t. 1, pt. 2, 660 p. Scaris.

Page 50, No. 2. Long description of species with references and notes as to habitat. "Habitat in shady gardens, forests, under stones, and here and there under fallen leaves."

1826. DEJEAN, le Comte. Species Général des Coléoptères, t. 2, 501 p.

Description, comparing this species with *C. sycophanta;* also some notes on a variety of *C. inquisitor, C. cupreum.*

1846. KIRBY, W., AND SPENCE, W. An Introduction to Entomology.

Page 454. Recorded as a pursuer and enemy of *Brachinus crepitans.*

1854. DAWSON, J. F. Geodephaga Britannica. A Monograph of the Carnivorous Ground-beetles Indigenous to the British Isles. xx+224 p., 3 pl. London.

Page 42. Description with notes on its occurrence in localities of Britain.

1865–1866. HARRIS, J. T. Calosoma inquisitor near Burton-on-Trent. *In* Ent. Mo. Mag., v. 2, p. 64; same *in* Entomologist, v. 2, p. 321.

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Pages 482–483. Includes full description of larva, and a note of its habitat. This is the first description of the larva so far as known.

1905–1907. HOULBERT, C., et MONNOT, E. Coléoptères, Carabides. *In* Trav. Sci. Univ. Rennes, Fauna Ent. Americaine, t. 1, pt. 2, p. 289–379, fig. 68–145.

Page 291. Includes figure and description of the species, also many localities in France where it has been reported.

CALOSOMA SAYI Dej.

(Syn.: *Calosoma armatum* Lap.)

ORIGINAL DESCRIPTION.

[Translation.]

Length 25 mm. Eastern and Southern States. Obscurely coppery above; elytra crenately striate; interstices equal, grooved transversely, punctures impressed, coppery-gold and longer than wide, raised, somewhat smooth, in triple row; intermediate tibiæ curved.

DISTRIBUTION.

This insect is represented in collections from Alabama, Arkansas, California, District of Columbia, Florida, Georgia, Illinois, Iowa, Kansas, Louisiana, Maryland, Missouri, New Jersey, New York, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia. It is also known to occur in Mexico.

COLLECTIONS AND SHIPMENTS.

Through the efforts of Prof. C. E. Sanborn, Stillwater, Okla., Mr. H. P. Loding, Mobile, Ala., and Mr. H. S. Barber of the Bureau of Entomology, the following living specimens of *Calosoma sayi* were received:

Table 16.—*Specimens of Calosoma sayi received in 1910 and 1912.*

Date received.	Number of specimens.		Locality in which collected.	Collector.
	Male.	Female.		
May 26, 1910		1	Washington, D. C.	H. S. Barber.
June 19, 1910	1		Stillwater, Okla.	C. E. Sanborn.
July 12, 1910	1	[1] 2	Mobile, Ala.	H. P. Loding.
July 14, 1910	4	2	Mobile, Ala.	H. P. Loding.
May 28, 1910		1	Washington, D. C.	H. S. Barber.
Total	6	6		

[1] One female was dead on receipt.

Mr. H. P. Loding, Mobile, Ala., under date of April 8, 1910, wrote the senior author the following concerning this species:

> Our most common Calosoma is *C. sayi* Dej., which occurs here in some numbers during the latter part of July. This insect is found frequently around electric lights in the city and I have also found it preying upon caterpillars of various species on low shrubbery and herbage.

This gives an idea of the occurrence and habits of the species in that section.

FOOD CONSUMED BY ADULTS.

Only a few feeding records were attempted and these are incomplete because many of the beetles died. A male received from Washington, D. C., May 26, and a female from Oklahoma, June 19, 1910, were fed in a jar from June 20 until July 21 and 23, when both died. One hundred and twenty-three full-grown caterpillars of *Malacosoma americana* and *Porthetria dispar* were consumed by the pair during the month they lived.

One female received from Washington, D. C., May 28, 1912, was fed in a jar until it sought hibernation August 30. Seventy-two caterpillars of *Malacosoma americana, M. disstria, Porthetria dispar,* and *Estigmene acraea,* ranging from fourth to sixth stage, were consumed. No eggs were deposited by this female and no male was available for a mate.

REARING AND HIBERNATION RECORDS, 1910–1912.

All the beetles received in 1910 were paired in jars, but neither copulation nor deposition of eggs followed, and all died at the end of that season. Only one female was received in 1912. As no males of this species were available, three males of *C. calidum* were placed in the jar with the female between June 8 and 13, but neither copulation nor reproduction ensued. The female was put into a hibernation cage August 30 and died late in the fall.

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Page 198. Original description of the species.

1831. DeJean, le Comte. Species Général des Coléoptères, t. 5, 883 p.
Page 558. Short note on the arching of the mesothoracic legs of the male.

1877. Popenoe, E. A. A list of Kansas Coleoptera. *In* Trans. Kansas Acad. Sci. f. 1876, v. 5, p. 21–40.
Page 22. Listed as rare in eastern Kansas.

1881–1884. Bates, H. W. Biologia Centrali-Americana. Insecta Coleoptera, v. 1, pt. 1, 316 p., 13 pl.

Pages 21, 262. This species believed by Mr. Gehin, according to Mr. Flohr, to be the same as *C. armatum* Lap.

1885. Riley, C. V. Coleoptera, or beetles which destroy *Aletia*. *In* 4th Rpt. U. S. Ent. Com., p. 95–97, figs. 14–16.

Page 95. Feeds on the cotton worm (*Aletia argillacea*), p. 95.

CALOSOMA SYCOPHANTA (L.).

[Pl. I.]

ORIGINAL DESCRIPTION.

[Translation.]

Gold-shining, thorax dark blue, elytra golden green, striate, abdomen somewhat black.

Habitat in Europe.

This is the largest species of the genus in Europe. The head and antennæ are black; the margins of the thorax and elytra golden. The elytra have 15 crenate striæ.

This insect was described by Linnæus. It is found more or less commonly in almost all European countries, especially in localities where lepidopterous larvæ are abundant, and is considered one of the most useful species of this genus on account of its ability to climb trees and its capacity for destroying caterpillars and pupæ.

HABITS OF ADULTS.

Extensive investigations have been carried on at the gipsy moth parasite laboratory, and careful studies have been made to secure all the information possible concerning the life history and habits of this species.[1]

Two important facts have recently been secured, namely, that the beetles may live four or more years, this having been determined by records secured from specimens reared at the laboratory and kept under observation for that period. It has also been determined that the beetles sometimes, and possibly quite frequently, enter hibernation and do not emerge until the second spring thereafter. Several careful records showing this peculiar habit have been obtained in the course of the investigation of this species.

DESCRIPTION OF LARVA.

First stage (Pl. X, *A*, *B*).—Average length of 12 newly-hatched specimens, from base of mandibles to posterior end of last abdominal segment (not including anal proleg or caudal appendages), 9.3 mm.; average width at mesothoracic segment, 2 mm.

The anal proleg is usually 1 mm. in length and the caudal appendages are about twice as long and taper gradually to the tips.

Color jet-black above; legs, antennæ, and mouthparts dark mahogany brown. If placed under a lens the body appears very dark brown, and the legs and mouthparts are of a somewhat lighter shade. Joints of antennæ, palpi, legs, and underside of body of a pearly color, except chitinous markings, which are jet-black. General outline of body fusiform. Antennæ longer than mandibles; maxillary palpi nearly as long as antennæ, tapering to tip of last joint; labial palpi stout, last segment cylindrical, truncate; prothorax wider than long. Second abdominal segment as wide as the first, body tapering quite abruptly beyond the 5th abdominal segment. Body

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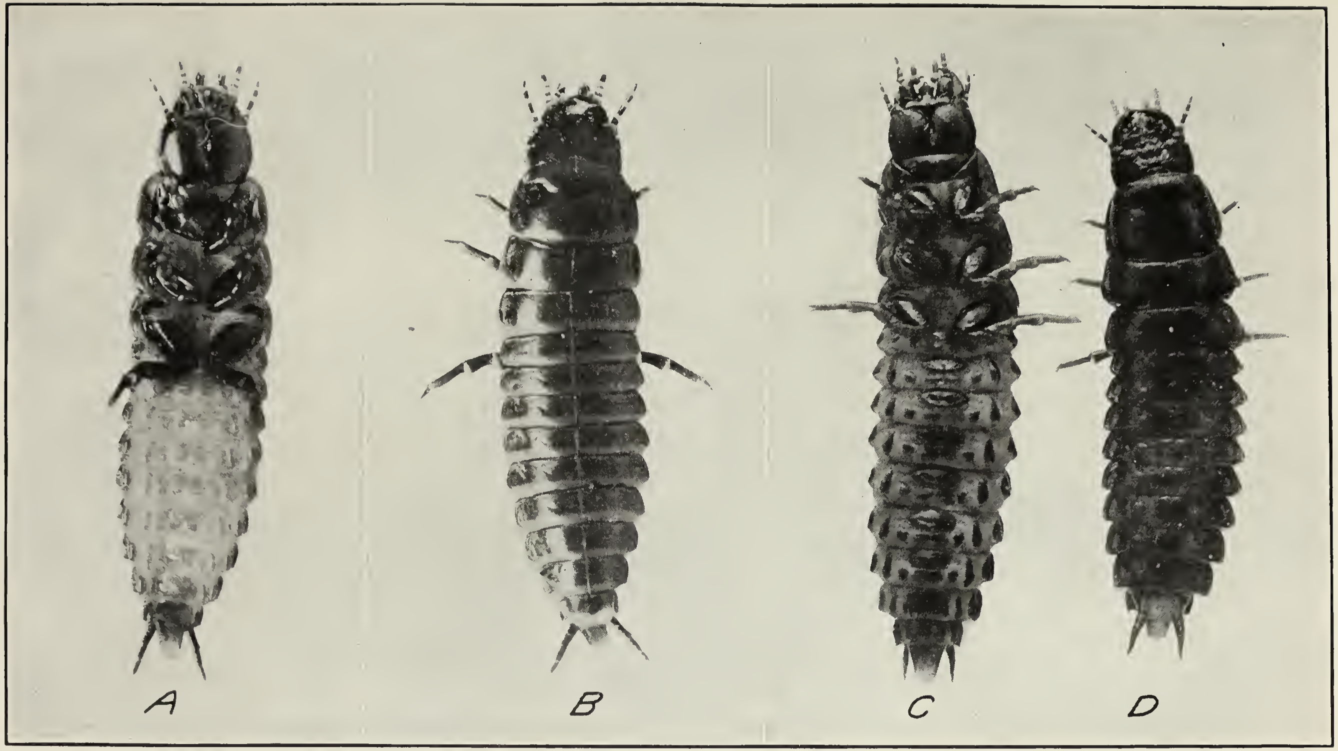
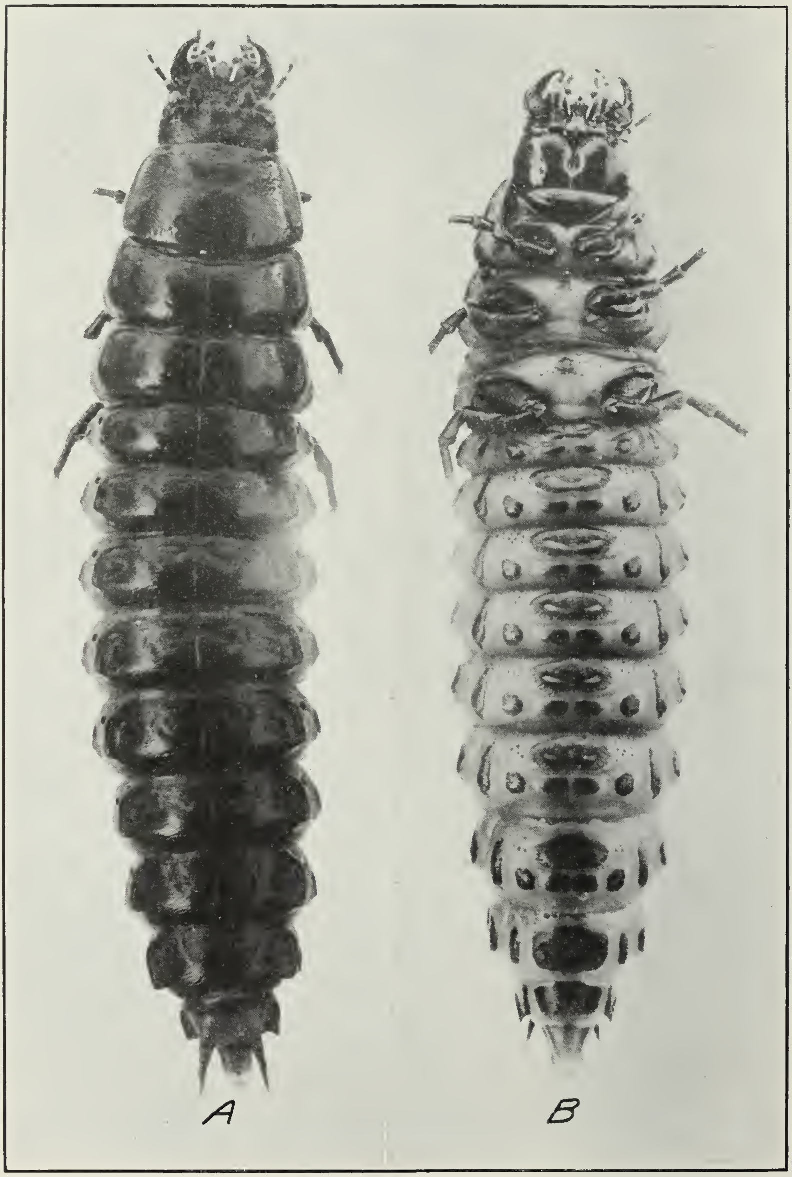
[1] Most of the information obtained has already been published in Bulletin 101 of the Bureau of Entomology, and the reader is referred to this publication for the principal details of this insect. (See also Bulletin No. 251, U. S. Department of Agriculture.)



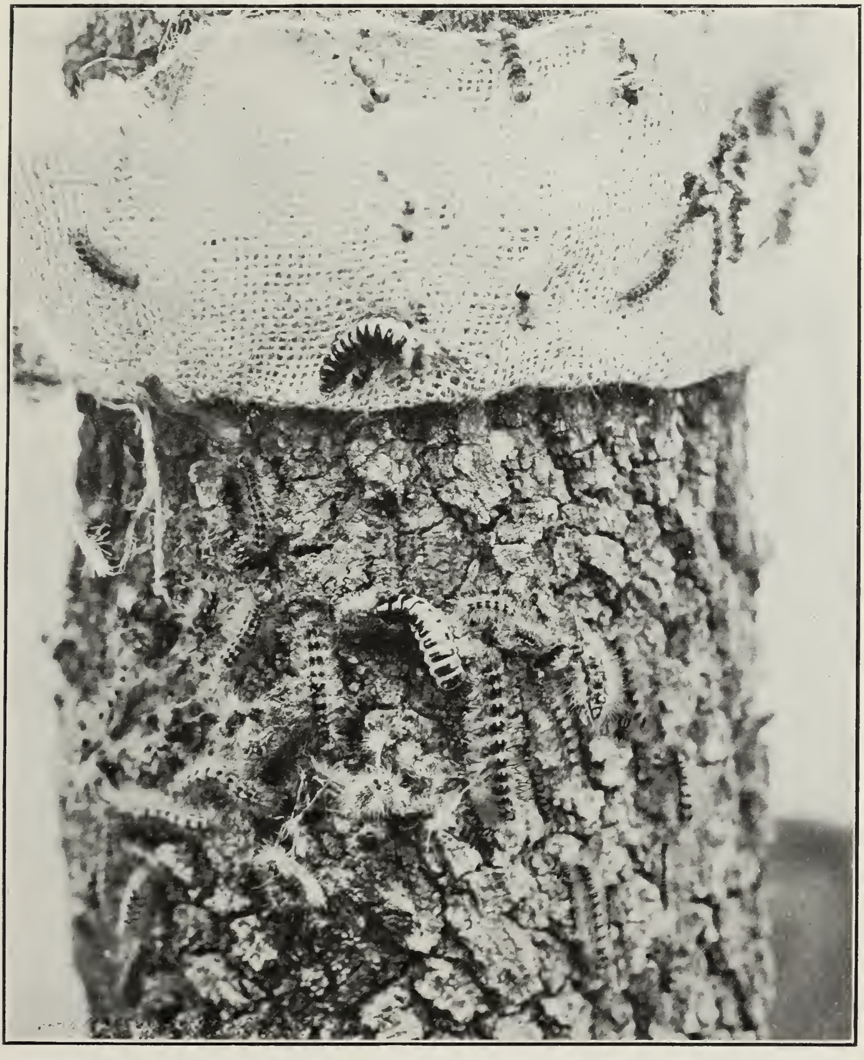
CALOSOMA SYCOPHANTA.

A.—First-stage larva, ventral view, ×6. *B.*—Same, dorsal view, ×6. *C.*—Second-stage larva, ventral view, ×4. *D.*—Same, dorsal view, ×4. (Original.)



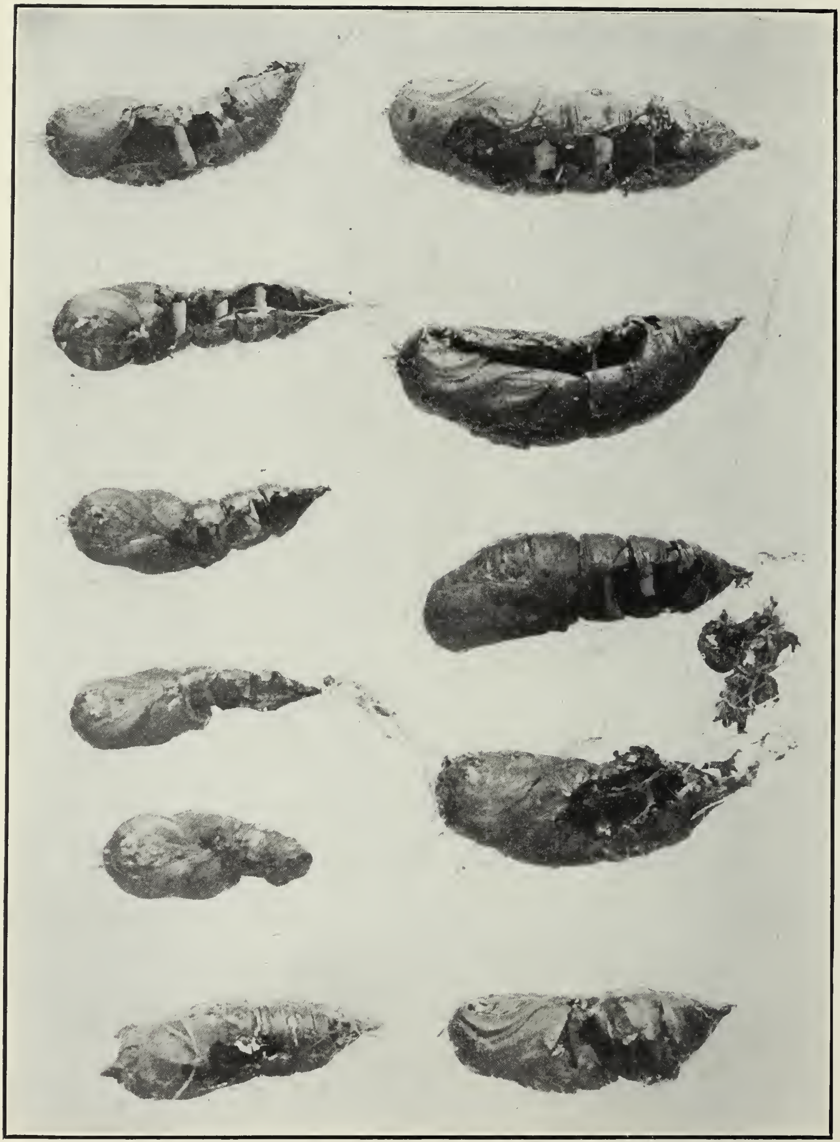
CALOSOMA SYCOPHANTA.

A.—Third-stage larva, dorsal view, ×4. *B.*—Same, ventral view, ×4. (Original.)



CALOSOMA SYCOPHANTA.

Larvæ of *Calosoma sycophanta* feeding on gipsy-moth caterpillars under burlap which has been turned up. (Burgess.)



BENEFICIAL WORK OF CALOSOMA SYCOPHANTA.

Pupæ of the gipsy moth that have been destroyed by the larvæ of *Calosoma sycophanta.* Note the irregular holes, which are characteristic. (Burgess.)

provided with rows of lateral and ventral spines. Legs spiny. Caudal appendages bearing a few spines.

Second stage (Pl. X, *C*, *D*).—Average length, 15.5 mm.; average width, 3.4 mm. Much stouter than first-stage larva. Body shining jet-black, mandibles and legs mahogany brown, mouthparts lighter, nearly honey yellow, dorsum of last abdominal segment and tip of proleg light brown. Caudal appendages relatively shorter than in preceding stage, each provided dorsally with a stout but short protuberance on its inner third, which bears a stout bristle.

Third stage (Pl. XI, *A*, *B*).—More robust than in previous stage. Average length, 25.8 mm.; average width, 5.7 mm. Body shining black in color; mandibles, legs, mouthparts, antennæ, and lateral and ventral abdominal markings dark brown. Prothorax much wider than long, wider behind. Dorsum of last abdominal segment and anal proleg chestnut brown. Dorsal abdominal plates nearly truncate behind; lateral margins of each raised and thickened, these margins more prominent on the last three segments. On the penultimate segment each dorso-lateral margin forms a stout, blunt, overhanging fold, while on the last segment each margin is drawn out into a stout tooth, pointing backward.

Median dorsal line prominent on all segments, except the last. Caudal appendages short, quite erect, with a large, stout, dorsal tooth, and a small lateral tooth, both of which are provided with spines.

HABITS OF LARVÆ.

The larvæ of this species are able to climb trees and are particularly successful in doing so on species that are provided with rough bark. All the larval stages of this beetle climb skillfully and feed upon caterpillars or pupæ that are resting on the bark (Pl. XII). Lepidopterous pupæ are especially favored as food by these larvæ, and as the gipsy moth is in the pupal stage during the time these larvæ are abundant in the field, the predacious larvæ are particularly adapted to destroy them. (Pl. XIII.)

DESCRIPTION OF PUPA.

Length, 25 mm.; width at first abdominal segment, 12 mm. Color pale yellow. Head depressed, only a small portion of the pronotum being visible from above. Dorsal part of thoracic segments smooth, shining. Lateral edges of first abdominal segment rounded behind. On the second to sixth segments, inclusive, the lateral edges are thickened, dark brown in color, and protrude slightly over the stigmata. The former are slightly hollowed out in front and bluntly toothed behind. The segments following are not thickened laterally. A thick brush of brown hairs is present on the dorsal part of the first five abdominal segments, as also a smaller one on the eighth segment; sometimes less prominent ones occur on the sixth and seventh segments. Spiracles somewhat protected by lateral brushes. Mouthparts, antennæ, wings, and legs folded beneath the head. Hind pair of legs extending to the tip of the abdomen. Wings extending beyond the fourth abdominal segment.

IMPORTATION OF CALOSOMA SYCOPHANTA.

This species has been collected in various European countries and shipped to Massachusetts for liberation in the field. It attacks the gipsy moth and many other lepidopterous larvæ and pupæ and has now become firmly established over a large part of the area in Massachusetts and New Hampshire that is known to be infested by the gipsy moth. The species has become so abundant in some of the infested towns that a large number of specimens have been collected and liberated in infested towns where the beetles were not known to occur. Small colonies of this insect have been shipped to New Mexico, California, and to New Brunswick, Canada, in order to test the ability of the species to become established in widely separated regions where the climate and food supply are dissimilar to those prevailing in New England.

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Page 212. List of references and description. The species is here listed under Weber's new genus *Calosoma.*

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Page 52, No. 4. Detailed description with references and notes on habitat in southern Switzerland.

1813. Panzer, G. W. F. Fauna Insectorum Germanicæ. Pt. I. Eleutherata, p. 41.

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Page 94. The species inhabits Europe, in Britain rare. A few records are given of the species having been collected in England and Ireland.

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CALOSOMA RETICULATUM (Fab.).

ORIGINAL DESCRIPTION.

[Translation.]

Winged, black, elytra reticulated, greenish-coppery, margin of thorax greenish. Habitat in Europe, Mus. Dom. Zechuck.

Stature and magnitude of *C. inquisitor.* Head, with antennæ, black, ferrugineous on the last joint. Thorax blackish, with golden reflexed margin. Elytra very finely reticulate, green, shining. Feet black.

EARLY RECORDS OF THE SPECIES.

The species was first described in 1787 by Fabricius as *Carabus reticulatus* and its habitat given as Europe. A more detailed description was given by Paykull in 1790 under the same genus with a note as to the scarcity of the species in southern Switzerland. Fabricius, in 1801, gave a further description of the species, placing it in the genus Calosoma and noting its occurrence in Germany. Latreille, in 1804, wrote that the species occurred in Germany, but very rarely. Gyllenhal published an account of the species in 1810 and included a note to the effect that it occurred rarely in southern Switzerland in shaded places. Dejean, in 1826, recorded it as occurring in Sweden, North Germany, and Austria, but very rarely everywhere.

All the information secured on this species from the literature and from the small numbers forwarded to the laboratory by Miss Marie Ruhl, Zurich, Switzerland, indicates that it is not common.

IMPORTATIONS.

The first importation of this species was received September 5, 1907, from Miss Ruhl, and contained one male and five females living and one female that had died en route. In 1908 50 males and 61 females alive, and 23 males and 15 females dead were received, and in 1910 a few specimens arrived.

The total receipts for 1907–1910, inclusive, were 172 specimens—52 males and 72 females alive and 28 males and 20 females dead. These notes would indicate that the species is not common in many localities of Europe, as Miss Ruhl received specimens from collectors at various points in France, Germany, Switzerland, and possibly other countries.

HABITS OF ADULTS.

Observations made on the climbing habits of these adults in 1911 revealed the fact that the beetles can climb trees when it is necessary to obtain food, but they ordinarily secure it on or near the ground like *Calosoma calidum.* They climb slowly and awkwardly, but when on the ground can travel swiftly. It has been proved that both adults and larvæ can and do ascend trees voluntarily, and it is believed from the meager results secured at the laboratory that they do this in all stages when the available food supply on the ground becomes exhausted.

HIBERNATION.

Four females were put into hibernation cages in the fall of 1907, and three of these emerged from May 16 to 30, 1908. Sixteen adults that were fed in jars during the summer of 1908 entered hibernation from July 30 to August 29 of that year, or an average date of August 17. Seven of the same beetles emerged the following spring between May 11 and May 27, or an average date of May 18. The depth of cavities of a few that entered hibernation in 1910 was about 1 inch.

One female that was reared in 1910, and issued as an adult July 15, came to the surface and fed until August 3 before entering hibernation. This female emerged May 15, 1911.

Accurate information as to the depth of cavities was difficult to secure without disturbing the beetles, but it is probable that they go deeper than 1 inch in most cases.

FOOD CONSUMED BY ADULTS.

Three pairs of beetles were fed in jars in 1908, but no reproduction resulted. Each female averaged 11½ small caterpillars per day from the date of emergence from hibernation to June 23, when males were received from Europe and placed in the jars. Fourth to sixth stage caterpillars of *Euproctis chrysorrhœa* and *Porthetria dispar* were supplied. After the males were added, June 23, the average per day for each beetle was two sixth-stage gipsy-moth caterpillars.

Feeding records were kept in 1909 of four pairs of beetles which were received from Europe in 1908, and the results secured are indicative that the species is a ravenous caterpillar hunter, as in one case a pair destroyed as many or more large caterpillars in a season than is normally killed by *Calosoma scrutator* or *C. sycophanta.*

TABLE 17.—*Feeding record of four pairs of Calosoma reticulatum, 1909.*

Pair No.	Feeding record started.	Ceased feeding.	*Malacosoma americana* third to sixth stages.	*Porthetria dispar*, sixth stage.	Total.
1504...	[1] May 27	[2] July 2	159	10	169
1506...	May 14	Aug. 13	504	24	528
1508...	[1] June 3	[2] July 7	196	18	214
1593...	May 15	[2] July 21	297	65	362

[1] Females fed on steak 8 to 10 days before records were started.
[2] Females died a few days later.

It will be noted from Table 17 that these beetles are voracious feeders. The average number of caterpillars consumed by each of the four pairs was 343 for the season of 1909. All of the females except No. 1508 reproduced. The average number of caterpillars consumed per day during the feeding season for pair No. 1508 was seven, and the average for the four pairs during the time each fed was six.

Pair No. 1506 lived to emerge from hibernation in the spring of 1910 and fed until July 2 before the female died. Two hundred and fourteen fifth and sixth stage caterpillars of *Noctua clandestina, Malacosoma americana*, and *Porthetria dispar* were consumed by the pair between April 27 and July 2, 1910. The pair reproduced in 1909 and 1910, which accounts for the large amount of food consumed each year.

Two pairs of beetles reared in the laboratory vivarium issued as adults in July, 1909, and came to the surface of the earth in the jars. Five sixth-stage caterpillars of *Porthetria dispar* were consumed by one pair and 13 by the other. All these beetles died during the latter part of July and the first half of August of the same year. This same habit of coming to the surface and feeding almost immediately after issuance as adults has been noted in the case of *Calosoma calidum*, but the beetles often died before the following spring.

REPRODUCTION.

Many specimens that were received from Europe in 1908 were kept in jars and cages for reproduction during the summer, but these did not reproduce until 1909 and 1910. Four females received in June, 1908, reproduced as follows in 1909: The first female deposited 39 fertile eggs between June 7 and 28 and died July 6; the second, 71 fertile eggs between June 14 and June 27, then ceased feeding and entered hibernation August 18; the third, 20 fertile eggs between

June 20 and 25, and died July 10; the fourth, 92 fertile eggs between June 15 and 30, and died July 28. The total number of larvæ that hatched from eggs of these four females was 222, or an average of 56 for each.

The second female, which deposited 71 fertile eggs in 1909, entered hibernation late in the summer, emerged the following spring, deposited 82 fertile eggs between May 26 and June 30, and died July 2, 1910. This female deposited a total of 153 fertile eggs in two seasons. Copulation was observed with the pair on May 20 and 28 and June 2 of the latter year. The females in some cases lived longer than the males. A few fertile eggs were also deposited in 1911 by two females—beetles received from Europe in July, 1910. One female reared in the vivarium at the laboratory in 1910, when placed with an old male in 1911, was observed to copulate, and on June 3 of that year it deposited one infertile egg before dying.

All the notes secured on the reproduction of beetles of this species tend to prove that they ordinarily do not reproduce the summer after issuing as adults. None of those received from Europe and confined in jars reproduced until the year following their receipt or later, and they were in their first year or older when received. The young female reared at the laboratory that deposited one infertile egg is an exception as far as the record goes, but this female died almost immediately thereafter. Most of the beetles passed the first year under abnormal conditions, as they were deprived of food during the long voyage to America, and this may in part explain their behavior.

LONGEVITY.

June 23, 1908, a large shipment of beetles was received from Europe, and eight pairs were confined in jars, while others were liberated in a colony. One pair of beetles, No. 1506, hibernated successfully for two winters and died, the female July 2, 1910, and the male September 2 of the same year. This pair of beetles were larvæ and pupæ in the summer of 1907 or earlier and lived three years or more. The female produced 71 fertile eggs in 1909 and 82 in 1910. No eggs were deposited in 1908. Many of the other beetles in this series died after one or two summers at the laboratory and may have been older when collected. Three years is probably the age limit in the adult stage for this species.

COLONIES.

June 28, 1908, the junior writer liberated 38 males and 45 females of this species in a wood lot in Winchester, Mass. An ample supply of caterpillars of *Porthetria dispar* was available, and the woods adjoined a market garden, where a greater or less number of cutworms were present. The species has not since been recovered, although occasional visits have been made to secure evidence of its presence.

In June, 1911, a larval colony of 27 specimens in the first and second stages was liberated in a garden in North Saugus, Mass., where cutworms were very abundant. This colony was very small and no evidence has been secured that the species has become established.

The attempts at colonizing this species in eastern Massachusetts have thus far been unsuccessful. There is a possibility, however, that recoveries may be made within a few years. It is believed that this species would be a valuable adjunct to the North American fauna, and the fact that the larvæ climb to some extent adds to their efficiency as caterpillar destroyers. It is expected that this would be a more valuable species for establishment in New England than *Calosoma auropunctatum*, although less is known about the larval habits of the latter.

THE EGG.

The eggs are yellowish white and elliptical in form, tapering toward one end. Twelve fresh eggs gave the following average measurements: Length, 5.5 mm.; width, 2.5 mm. The size varies, but they run somewhat larger than those of *Calosoma sycophanta*, although the adults average considerably smaller.

Hatching data were secured on 89 eggs deposited between June 3 and 22, 1909, and the time in the egg stage ranged from 4 to 14 days, or an average of 10. Similar data were again secured in 1910 for 82 eggs deposited between May 26 and June 30, and the number of days passed ranged from 5 to 20, or an average of 13. In 1911, 54 eggs were deposited between May 22 and June 20, the period in the egg stage ranging from 5 to 12 days, or an average of 8. Most of the eggs included in the record of 1910 were deposited during the latter part of May, when the temperature was much lower than for those deposited in June, 1909. The records secured in 1911 are rather similar to those of other species studied.

BRIEF DESCRIPTION OF LARVA.

First stage (Pl. XIV, *A*, *B*).—Of medium size, fusiform. Average length of 12 specimens, 11 mm.; width, 3 mm. Caudal appendages long, straight, tapering gradually from base to apex, bearing numerous long spines. Color glossy black.

Second stage (Pl. XIV, *C*, *D*).—Average length of 10 specimens, 18 mm.; width, 3.6 mm. Caudal appendages rather erect, tip curved backward. Color, shining black above. No reddish-brown patch on dorsum of last segment.

Third stage (Pl. XV, *A*, *B*).—Robust in form. Average length of 8 specimens, 25.7 mm.; width, 5.3 mm. Caudal appendages short, erect, but slightly curved downward beyond dorsal protuberance, which is rather short and arises slightly more than one-half the distance from base to tip. Color shining black dorsally. Ventral plates dark brown. No reddish-brown patch at base of caudal appendages.

TIME REQUIRED TO COMPLETE LARVAL STAGES.

Observations were made on a series of the larvæ fed in 1909 and 1910 to ascertain the time required for the completion of the different larval stages. From those observed in 1909, which hatched June 21 to 28, an average of 3 days was required for the first stage, 4 for the second, and 14 for the third to the time when feeding ceased. Another small series reared in 1910, which hatched June 13 and 14, required an average of 6 days for the first stage, 4½ for the second, and 9 for the third.

Some of the larvæ of the series of 1909 molted in 2 days after hatching, which is unusual, as 4 days is common with most species of Calosoma.

From 3 to 7 days were passed by the larvæ in making a cavity and preparing for pupation. A fair average covered by this period is 4 or 5 days, making the total number passed in the larval stages 25 to 26 days.

FOOD CONSUMED BY LARVÆ.

Daily records were kept of a series of larvæ reared in 1909 and 1910. It was observed that the larvæ destroy and consume large numbers of caterpillars in comparison to larvæ of *Calosoma calidum.* Large caterpillars of *Malacosoma americana* and *Porthetria dispar* were offered for food. A few records follow:

TABLE 18.—*Food eaten by larvæ of Calosoma reticulatum, 1909, 1910.*

No.	Date hatched.	Date ceased feeding.	*Malacosoma americana* caterpillars, fourth to sixth stages.	*Porthetria dispar* caterpillars, sixth stage.	Total.
	1909	1909	1909	1909	1909
1506A	June 21	July 8[1]	6	20	26
1506B	...do.....	14	8	31	39
1506C	...do.....	12	5	33	38
1506D	...do.....	16[1]	6	23	29
1506F	...do.....	12[1]	7	29	36
1506I	...do.....	12	7	37	44
	1910	1910	1910	1910	1910
1506AB	June 13	July 5[1]	[2] 6	22	28
1506AC	...do.....	2	[2] 5	29	34
1506AD	...do.....	June 30	[2] 4	15	19
1506AE	...do.....	July 4	[2] 4	45	49
1506AF	June 14	5[1]	[2] 5	35	40
1506AG	...do.....	6[1]	[2] 4	45	49

[1] Full-grown larva died. [2] All sixth-stage caterpillars.

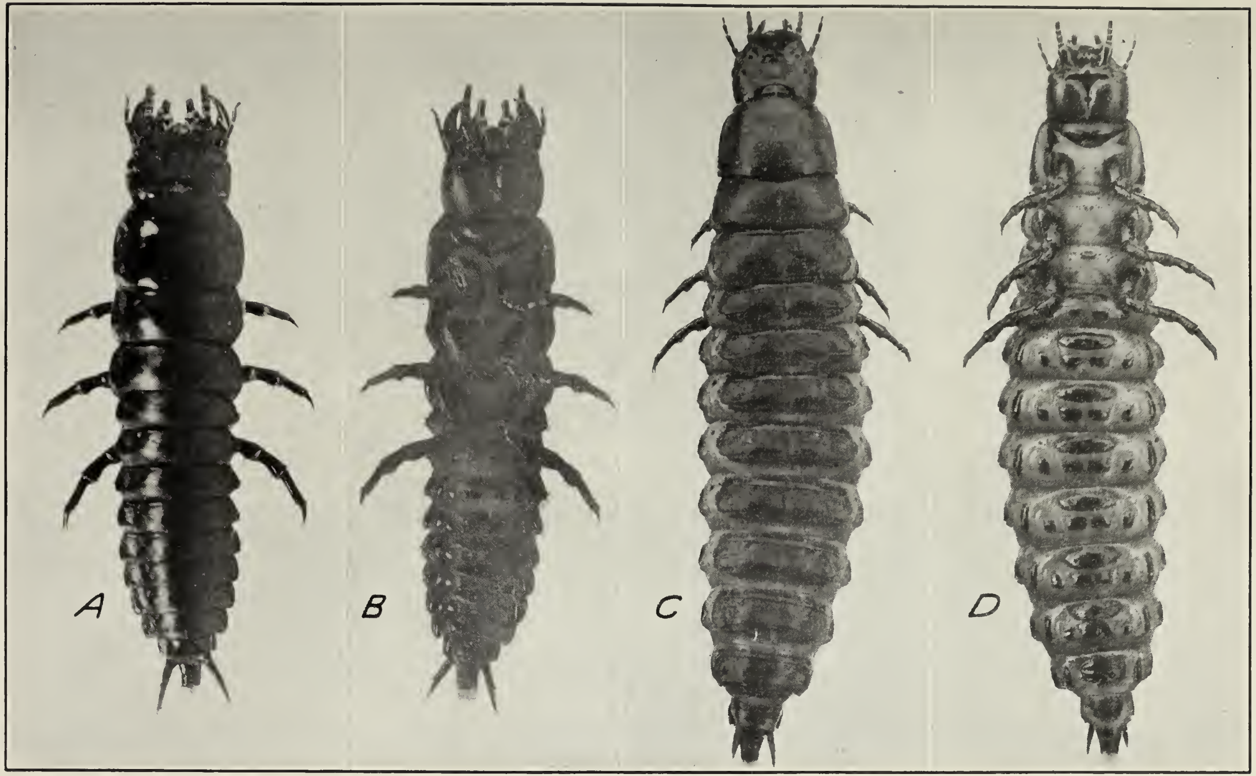
Very little variation was found between the two series, as an average of 36 caterpillars was destroyed by 6 specimens fed in 1909 and 37 by the same number in 1910. The larvæ in both series continued their activity and feeding over an average period of 21 days. The same period is required by larvæ of *Calosoma calidum.*

Three larvæ were fed to maturity in 1911 on pupæ of *Malacosoma americana* after the latter had been stripped from their cocoons, and when necessary large caterpillars were substituted. Ten pupæ were killed and wholly or partly devoured by the first-stage larvæ, nine pupæ and three fifth-stage caterpillars by the second-stage larvæ, and nine pupæ and three sixth-stage caterpillars by the third-stage larvæ. Assuming that about the same amount of food was contained in a large caterpillar as in a pupa, an average of 11 to 12 pupæ were consumed to complete the larval growth.

HABITS OF LARVÆ.

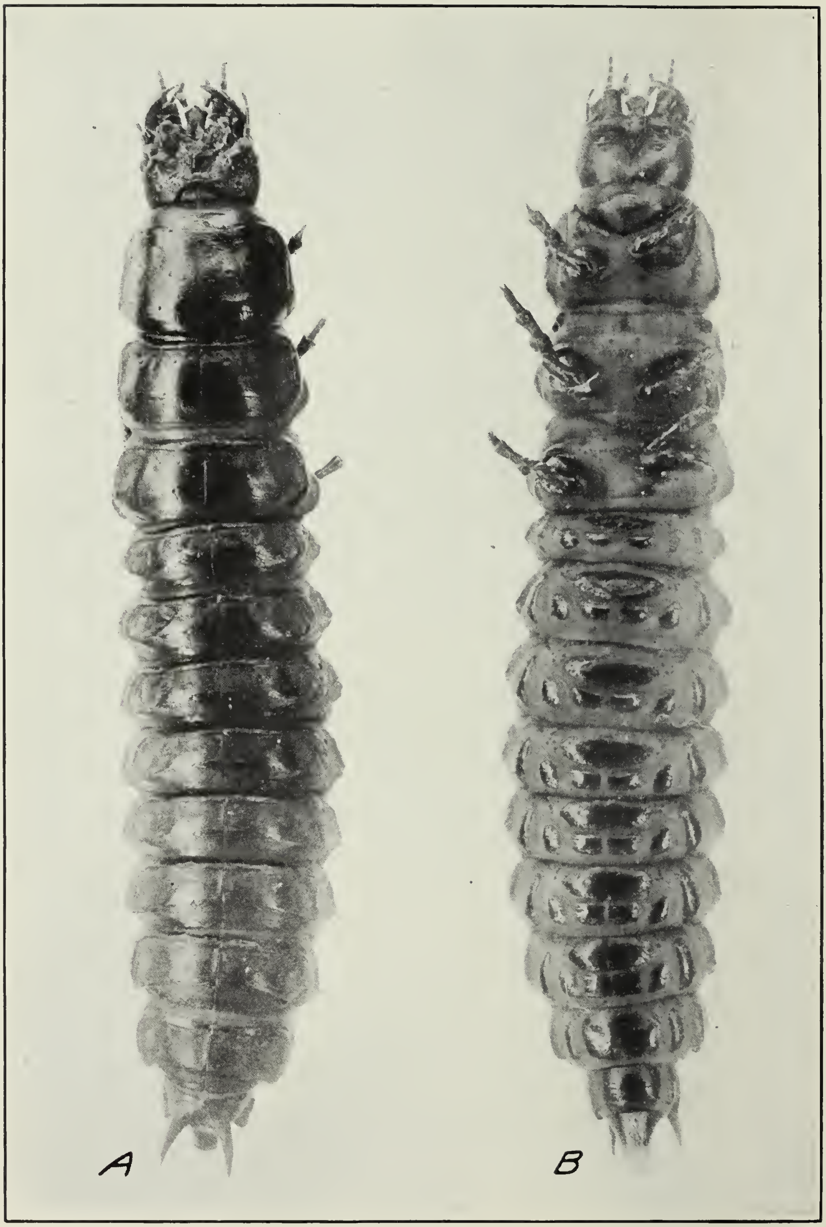
During the spring and summer of 1911 data were collected in an experimental way to determine the climbing habits of these larvæ.

May 29 six young first-stage larvæ were tested (Pl. III), and one of them immediately climbed upon the tree to a height of 5 feet, then fell to the ground. This larva climbed with considerable ease. Another specimen ascended 1½ feet before falling. June 5 all the larvæ had molted and made no attempt to climb of their own volition while they were under observation. They were put upon the bark



CALOSOMA RETICULATUM.

A.—First-stage larva, dorsal view, ×6. *B.*—Same, ventral view, ×6. *C.*—Second-stage larva, dorsal view, ×4. *D.*—Same, ventral view, ×4. (Original.)



CALOSOMA RETICULATUM.

A.—Third-stage larva, dorsal view, ×4. *B.*—Same, ventral view, ×4. (Original.)

at various times, but did not climb more than 4 or 5 inches. These larvæ were then removed and others substituted. June 24 two first and two second stage larvæ were tested, and one climbed 2 feet before falling. June 25 at 8 a. m. one of the second-stage larvæ was found on the bark of the tree 18 inches from the ground, but there were no signs that it or the others had entered the food cage at the top during the night.

June 26 a sixth-stage caterpillar of *Porthetria dispar* was found devoured in the food cage at the top, evidently by a third-stage larva, as there was a large hole in one side of the caterpillar where it had entered. A second-stage larva when placed upon the tree crawled up 18 inches before falling.

June 27, in the forenoon, a third-stage larva was found on the bark 15 inches from the ground, but it had not entered the food cage during the night.

June 28, in the forenoon, the same larva was again found on the bark of the tree 6 inches from the ground.

June 29, in the forenoon, a third-stage larva was found in the food cage at the top of the tree, and had devoured a sixth-stage caterpillar.

July 3 a second-stage larva was found in the earth at the base of the tree, but had entered the food cage at the top during the night and devoured two sixth-stage caterpillars of *Porthetria dispar*.

July 4 it was again noted that the larva had entered the food cage and devoured another large caterpillar.

July 5 the same operation was again noted except that this time a part of two caterpillars had been consumed. July 11 the larva died after growing weaker for two or three days. It had probably been injured in falling.

These experiments reveal the fact that larvæ of this species can and do climb in all stages. The first-stage larvæ did not quite reach the food cage at the top while the second and third stage larvæ seemed to have easy ingress and egress. These results compare quite favorably with the climbing habits of larvæ of *Calosoma sycophanta*.

CANNIBALISM AMONG LARVÆ.

An experiment was conducted in the summer of 1909 to find out how many days after hatching these larvæ could be fed together in jars before planting them in colonies in the field. They were confined in large battery jars about 8 inches deep and 6 inches in diameter with about 2 inches of earth in the bottom. Caterpillars of *Porthetria dispar* were supplied daily with fresh leaves so as to keep them feeding on the earth and to enable the larvæ of *Calosoma reticulatum* to reach them easily. The larvæ hatched between June 21 and June 29, 1909, and were all removed from the jars, July 1. The results are given in Table 19.

TABLE 19.—*Extent to which larvæ of Calosoma reticulatum prey on one another.*

Number of days after hatching.	Per cent alive when removed.	Number of days after hatching.	Per cent alive when removed.
Days.		*Days.*	
11	21	6	43
10	25	5	40
8	20	3	94
7	6		

The results obtained show that the larvæ prey upon one another to a great extent after the third day, or about the time they enter the second stage. The same is true with the other species of Calosoma thus far studied. However, the writers have fed larvæ of *C. sycophanta* on pupæ of *Porthetria dispar* in this manner to the end of the second stage without suffering heavy losses from cannibalism. Pupæ are more desirable than caterpillars for food, as they do not move on the surface of the earth, whereas caterpillars are continually crawling about the sides of the jar, where they are out of reach of the beetle larvæ.

THE PUPA.

[Pl. XVI, *A*, *B*, *C*.]

The average length of three females was 19.2 mm. and the width 7.9 mm. The average length of two males was 16.3 mm. and the width 7.9 mm.

Adults were reared in the laboratory vivarium in 1909 and 1911, and data on the time required to complete the pupal stage were secured each year. Many times the larvæ were not considerate enough to make their cavities at the side or bottom of the glass jars in which they were confined, so that it was difficult to secure exact notes on the time of entering and completing this stage.

One larva, No. 1506–I, ceased feeding July 12, 1909, and buried itself in the earth for pupation. A female issued July 23. About 5 days were passed in the prepupal stage and 13 days as a true pupa. One larva, No. 1506–AC, ceased feeding July 2 and pupated about July 5, but the adult died when emerging, July 17. In this case 3 or 4 days were passed in the prepupal stage and 11 or 12 days as a pupa. Other data obtained during those years and in 1911 gave similar results.

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CALOSOMA ANGULATUM Chev.

ORIGINAL DESCRIPTION.

[Translation.]

So. Calif. Length 27 mm.

Blackish-blue. Head punctate. Thorax black, angled in the middle, marginate and dark blue on the sides, smooth, punctate at base and apex, with longitudinal line scarcely impressed. Elytra with 14 ribs, interstices latticed, deeply towards the humerus, striate-punctate, with three rows of oblong punctures more marked in the single beetle examined; apex acutely rounded.

EARLY RECORDS AND DISTRIBUTION OF THE SPECIES.

This species was described by A. Chevrolat in 1834, the type specimen being taken in southern California. The description refers to 14 ribs or elevations on the elytra. A careful examination was made of the specimens in the LeConte collection in the Museum of Comparative Zoology, Cambridge, Mass., and 16 elevations were noted in each case. There has been some confusion between *Calosoma angulatum* Chev. and *Calosoma angulatum* Lec., but the latter name was changed to *prominens* by LeConte. *Calosoma angulatum* Chev. has been taken in Arizona, California, and Texas. There is also a record from Mexico where it probably occurs in many localities.

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Pages 21 and 262, pl. 2, fig. 12. Habitat notes in several localities of Mexico. "A closely allied but sufficiently distinct species (*C. angulicolle* Chaud.) occurs near Santa Marta, Columbia."

CALOSOMA PEREGRINATOR Guer.

(Syn.: *C. carbonatum* Lec.)

ORIGINAL DESCRIPTION.

[Translation.]

Body wholly black, almost entirely dull on the dorsal surface, a little shining on the ventral side. Head small, very heavily granulated with an oblique dimple in front, near the insertion of the antennæ. Thorax transverse, truncate, nearly straight to its two extremities, angular at each side in the middle, with the space between the lateral angle and the anterior margin rounded, with the space between the lateral angle and the inferior margin rounded; and the space between this same angle and the lower margin cut off straight. Its disc finely granulate, with the edges more heavily wrinkled and a feeble longitudinal line sunken in the middle. Shield small, triangular. Elytra very much broader than the thorax at their base, elongate, rounded anteriorly and posteriorly, nearly parallel in the middle, heavily margined, presenting some 14 or 15 lines of small sunken dots, gradually disappearing towards the posterior extremity of the elytra, and three series of distant dots, scarcely visible, without the aid of the lens. Underside of the body and the feet nearly smooth; some large sunken dots on the lateral sides of the metathorax and the first abdominal segment, the following very finely striate longitudinally to the middle.—L. 0,026; l. 0,011.

This species is distinguished from all those which have been described by M. Dejean by reason of its thorax of angular margins. It approaches the character of *C. angulatum* of M. Chevrolat (Col. du Mex., fasc., 2 mars 1843). But with this latter the elytra have each fourteen elevations.

EARLY RECORDS OF THE SPECIES.

This species was described by M. Guérin Méneville, in 1844, from specimens collected in Mexico. He erroneously reduced *C. prominens* Lec. to a synonym of this species. In 1863 LeConte described a new species as *C. carbonatum*, but this was recognized as a synonym of *C. peregrinator* Guér. by G. H. Horn, in 1883, and was so published by Mr. H. W. Bates during the following year.

The writers have studied the descriptions and compared labeled specimens and have reached the same conclusion.

DISTRIBUTION.

Museum specimens indicate that this species has been collected at an altitude of 4,400 to 6,000 feet in New Mexico and Texas. It has also been taken in Arizona, California, Kansas, and New Mexico. Numerous cases are also on record of the species having been collected in Mexico.

COLLECTIONS AND SHIPMENTS.

Dr. A. W. Morrill, of Phoenix, Ariz., in the latter part of August, 1912, wrote that both adults and larvæ of this species were fairly common near Prescott, Ariz., and were feeding upon the variegated cutworm. He forwarded to the laboratory at the same time one pair of live adults and four third-stage larvæ, two of which were dead on arrival. Under date of October 8, five pairs of adults, one female of which was dead, were received from Mr. L. L. Bates, Prescott, Ariz., an assistant of Dr. Morrill. The beetles were placed in jars of earth for study.

HABITS OF ADULTS.

One pair of the beetles received October 8 were put at the base of the tree to test their ability to climb. (Plate III.) Both beetles climbed to the top of the tree without urging and remained there until removal. They were left at the base of the tree in the afternoon and on the following morning were again found at the top. The beetles climb rather slowly in comparison to adults of *C. frigidum* Kirby, or *sycophanta* L., and probably secure most of their food near the ground.

FEEDING RECORDS OF ADULTS.

Beginning October 8, 1912, daily feeding records were kept of two pairs in the hope that they might reproduce. The jars were kept inside the laboratory and the beetles remained active until December 2, when the food supply became exhausted. On this latter date the jars were transferred to the cellar and the beetles entered hibernation in a few days.

TABLE 20.—*Feeding record of two pairs of Calosoma peregrinator, 1912.*

Pair No.	Record started.	Transferred to cellar for hibernation.	Full-grown larvæ and pupæ of *Pontia rapæ* and *Plusia brassicæ* consumed.
5867	Oct. 8	Dec. 2	334
5868	do	do	268

From 10 to 16 full-grown larvæ were consumed some days by a single pair. The average larvæ consumed per day for the first pair, No. 5867, during the feeding period was 6. The beetles in question did not reproduce during the fall of 1912. The same pair issued from hibernation June 8 and had consumed 122 fifth and sixth stage larvæ of *Malacosoma americana* and *Porthetria dispar* by July 21. On this date the male died, and as the female ate very little the record was discontinued temporarily. On September 10 the female began feeding ravenously and consumed 48 large larvæ of *Hyphantria cunea* during the next 19 days.

The records secured are too incomplete to form an accurate idea of the value of this insect as a destroyer of lepidopterous larvæ. They indicate, however, that under favorable natural conditions it is an important species.

HIBERNATION.

Of the small lot of adults received during the fall of 1912 a few after feeding for a period entered the earth for hibernation. The jars were then filled with earth and transferred to the laboratory cellar, where the temperature ranged from 40 to 65° F. during the winter, as it was thought that this species could not withstand the severe weather outside. Two pairs were living when the jars were taken outside in the spring and could be seen in their cavities. One pair of these beetles came to the surface for food September 10 and 23, respectively. The other pair was still in cavities in the jar. The male of the latter jar emerged for food August 31, 1914, the female dying in its cavity that summer.

REPRODUCTION.

Only one pair of the beetles issued from hibernation in the spring so as to reproduce at the normal time of other species of the genus. The female of this pair issued June 8, 1913—the male remaining on the surface all winter, as the jar where they hibernated was kept in the cellar. Copulation was observed June 11 and 30. Eggs were removed from the jar June 28 and 29 and July 3 and 4. Eight larvæ hatched. The male died July 21 and the female during hibernation the following winter.

DESCRIPTION OF LARVA.

First stage.—Robust in form, tapering gradually to anal end. Average length of five alcoholic specimens, 8.2 mm.; width, 2.1 mm. Caudal appendages rather long (1.8 mm.), slender, tapering gradually from base to apex, bearing numerous long spines. Dorsal protuberance indistinct in this stage. Color brownish-black on the dorsum, ventral plates grayish-brown. Anterior ventral plates broad in middle and tapering to a point at each end.

No second-stage larvæ were available for description.

Third stage.—Very robust in form, broad. Length of one alcoholic specimen that had fed to some extent in this stage, 23.5 mm.; width, 6.5 mm. Caudal appendages almost straight, slender, only slightly angled downward beyond dorsal protuberance. Protuberance short, erect, located more than one-half distance from base to tip. Color dull to shining black, ventral plates dark brown. Pronotum nearly square, but rounded on anterior angles. Tergites projecting slightly laterad in partly fed larvæ, with posterior angles obtuse, except the seventh and eighth abdominal, and pointing slightly backward. Posterior angles of seventh, eighth, and ninth tergites rather acute; angle of ninth very small, not prominent. No reddish-brown patch on dorsum of anal segment.

NOTES ON LARVÆ AND PUPÆ.

One female pupa measured 20.5 mm. long and 9 mm. wide.

Two live third-stage larvæ were received September 4, 1912. One died September 5 without feeding and the other consumed the greater part of a full-grown larva of *Estigmene acræa* and one of *Papilio turnus*, and entered the earth September 8. A cavity was formed and pupation took place September 12 or 13. The pupa was removed to the top of the earth for study and although the specimen was not allowed to develop to the adult stage, it was evident that about 14 days are spent as a pupa.

A few larvæ hatched from eggs in 1913, but all died in the first and second stages. Large caterpillars and pupæ of *Porthetria dispar* were offered, and the beetle larvæ fed upon them readily.

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Page 255. Original description of the species and comparisons made of the angled thorax to that of *C. angulatum* Chev.

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Page 22. "Western Kansas."

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Page 270. The writer places *C. carbonatum* Lec. as a synonym of *C. peregrinator* Guér. and also corrects the misunderstanding that *C. prominens* Lec. is a synonym of the latter species.

1881–1884. Bates, H. W. Biologia Centrali-Americana, v. 1, pt. 1, 316 p., 13 pl.

Pages 21, 262. The writer quotes Flohr as classing *C. carbonatum* Lec. as synonymous with *C. peregrinator* Guér. He also states that *C. peregrinator* Guér. and *C. prominens* Lec. are distinct species, although LeConte had promised to unite the latter to the former.

1893–94. Horn, G. H. The Coleoptera of Baja California. *In* Proc. Cal. Acad. Sci., 2d ser., v. 4, p. 302–449, pl. 7–8.

Page 307. *C. carbonatum* Lec. is given as a synonym of *C. peregrinator* Guér. with habitat as localities in southwestern United States and Mexico.

1897. Coquillett, D. W. Revision of the Tachinidae of America north of Mexico. U. S. Dept. Agr. Div. Ent. Tech. Ser. No. 7, 154 p.

Page 10. Coquillett records the breeding of *Biomyia georgiæ* from *Calosoma peregrinator* at Los Angeles, Cal., June 25, 1888.

CALOSOMA PROMINENS Lec.

ORIGINAL DESCRIPTION.

Black; head very variably punctate, deeply impressed on both sides, thorax much wider than long, sides angled acutely, with margin scarcely reflexed, narrowed at base, somewhat rounded, finely wrinkled, punctate at posterior, elytra shining, finely punctate in rows, punctures larger towards the base, interstices scarcely corrugated. Length 1.3. Dead specimen about Pimas, Calif.

This species was described by Le Conte in 1851 as *Calosoma angulatum*, but this name was preoccupied, having been used in 1834 by A. Chevrolat for a very different species of Calosoma from southern California. LeConte discovered this fact, and in 1853 proposed the name *prominens* for this species with the angled thorax. It has been recorded from several localities in Arizona, California, and New Mexico, and occurs in Mexico.

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1853. LeConte, J. L. Notes on the classification of the Carabidæ of the United States. *In* Trans. Amer. Phil. Soc., v. 10, n. s., pt. 3, art. 27, p. 364–403.

The writer announces the preoccupancy of *Calosoma angulatum* by Chevrolat and proposes to call his new species, also with angled thorax, *Calosoma prominens.*

1881–1884. Bates, H. W. Biologia Centrali-Americana, Insecta, Coleoptera, v. 1, pt. 1, 316 p., 13 pl.

Pages 21, 262. The author had the opportunity of examining Guérin's type of *C. peregrinator* along with a large series and states with certainty that it is quite distinct from *C. prominens.* LeConte, himself, at one time proposed to unite them.

1893–1894. Horn, G. H. The Coleoptera of Baja California. *In* Proc. Cal. Acad. Sci., 2d ser., v. 4, p. 302–449, pl. 7–8.

Page 307. Notes on habitat as follows: "Western Arizona, southern Mojave region, northern Sonora, El Taste."

CALOSOMA PARVICEPS Casey.

ORIGINAL DESCRIPTION.

Rather stout, with relatively very small head and prothorax, deep black, and devoid of metallic reflection throughout, the integuments rather shining. Head three-fifths as wide as the prothorax, evenly and feebly convex, not rugose but finely, evenly and rather closely punctured, becoming smooth at apex where the lateral impressions are narrow and very deep; labrum dilated and rounded at the sides, transverse at apex, with a broad and very shallow median sinuation, the surface transversely impressed; antennæ short and rather stout, only slightly longer than the head and prothorax, the third joint fully three times as long as the second. Prothorax moderately transverse, about four-fifths wider than long, widest at the middle where the sides are obtusely and somewhat bluntly angulate, thence very moderately convergent and broadly, evenly arcuate to the apex, oblique and straight behind, becoming slightly sinuate near the base, the latter rather narrower than the apex and somewhat as in the preceding species; disk broadly and very feebly convex, polished, feebly wrinkled, finely and rather sparsely punctate, the punctures becoming coarser and subcoalescent at the sides, more numerous in the impressions near the basal angles; side margins defined by a rather thin, strongly reflexed bead; median line fine and very feeble. Elytra oblong, scarcely more than one-third longer than wide, fully twice as wide as the prothorax, only slightly wider at apical third than at base, the sides very feebly arcuate and very narrowly reflexed; disk moderately convex, with scarcely impressed even series of extremely fine punctures, which become stronger toward base, the intervals there becoming transversely broken by arcuate impressed lines as in *peregrinator*, the three series of interstitial asperate punctules very feeble; marginal punctures visible only toward base, the submarginal asperate punctures rather widely separated and uneven. Legs moderate in length and quite slender. Length 16.5 mm.; width 7.5 mm.

The anterior tarsi of the male have the first three joints rather feebly dilated and densely pubescent beneath, the pad of the first joint small and apical; the hind trochanters and intermediate legs are not modified. *Parviceps* also belongs near *peregrinator*, and greatly resembles the preceding species at first glance; it however, differs in sculpture, structure of the labrum, in its much deeper epistomal impressions, less transverse prothorax with less rounded side angles, shorter and broader elytra and in several other minor characters.

This species was described by Col. Thos. L. Casey in 1897.[1] The type specimen or specimens were taken in Arizona. The description compares this species to *peregrinator* Guér., but it is much smaller than the latter. The species has also been recorded from San Diego and San Clemente Island, Cal.

CALOSOMA LUGUBRE Lec.

ORIGINAL DESCRIPTION.

Black, shining, face sparingly punctate, short thorax, with sides much rounded and somewhat angled, truncate at the base, broadly depressed on both sides; with elytra broader than the thorax by one-half, punctate in series, with punctures larger towards the base and grooves transverse and joining. Length 1.08 inches.

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[1] Casey, T. L. Coleopterological notices. *In* Ann. N. Y. Acad. Sci., v. 9, p. 285–683 (p. 341–342), 1896–1897.

EARLY RECORDS OF THE SPECIES.

The writers have been able to find very little published on this important and interesting species. Le Conte described it in 1853, but no note was incorporated in the description as to the location from which it was taken. Prof. L. Bruner, in 1890, noted it with *C. externum* partly devouring May beetles which were flying to lights in large numbers. Dr. W. D. Hunter of the Bureau of Entomology and his assistants have observed large numbers of these beetles in Texas flying to lights at night during September and October.

DISTRIBUTION.

Collection data at hand show that this species occurs rather commonly at various times in Texas and Kansas, for it has been reported from many localities in these States. It has also been taken in Oklahoma, Nebraska, and New Mexico, and it probably exists in other States.

COLLECTIONS AND SHIPMENTS.

September 23, 1909, Mr. W. F. Fiske, recently of the Bureau of Entomology, was in San Antonio, Tex., and observed numerous specimens flying about electric lights. He collected eight males and eight females and shipped them to the laboratory, one male and one female being dead on arrival September 29.

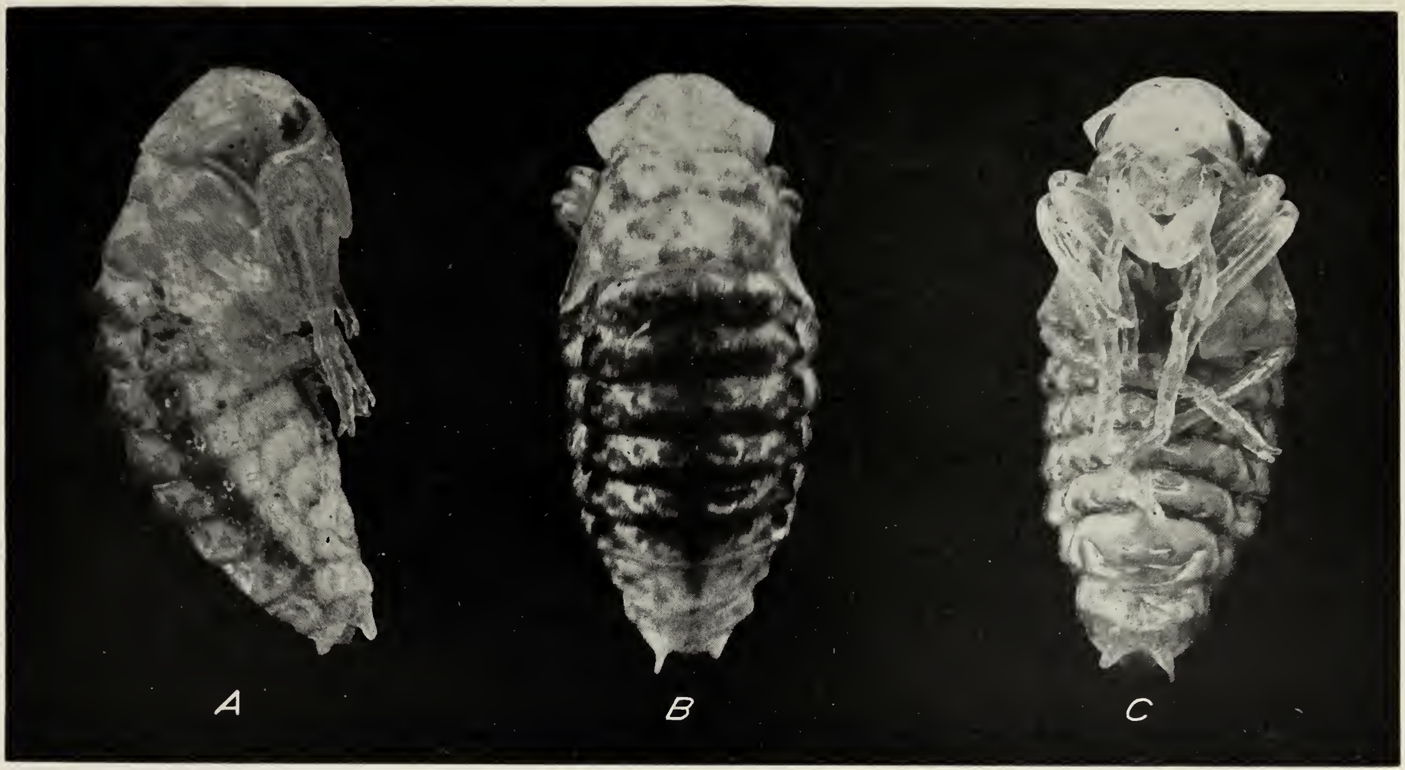
June 19 and July 6, 1910, 15 males and 19 females were received at the laboratory from Prof. C. E. Sanborn, Stillwater, Okla. August 29 of the same year 1 female was received from Mr. W. M. Orr, Manhattan, Kans.

April 26, November 11, and November 13, 1911, a total of 29 males and 47 females was received from Dr. Hunter and Mr. J. D. Mitchell from Dallas and Victoria, Tex. Between April 18 and 30, 1912, Mr. Mitchell collected and shipped from the latter point 103 males and 71 females.

The beetles were packed singly in pill boxes which were inclosed in pasteboard or cigar boxes and forwarded by mail. No food was supplied them en route and they arrived in excellent condition.. These large collections show that the species is common at times in Texas and Oklahoma. Dr. Hunter on November 1, 1911, wrote Dr. L. O. Howard to the effect that they were seeing at that time an abundance of *C. lugubre* around arc lights at night and that it would be possible for a man to collect several hundred specimens at electric lights in an hour's time.

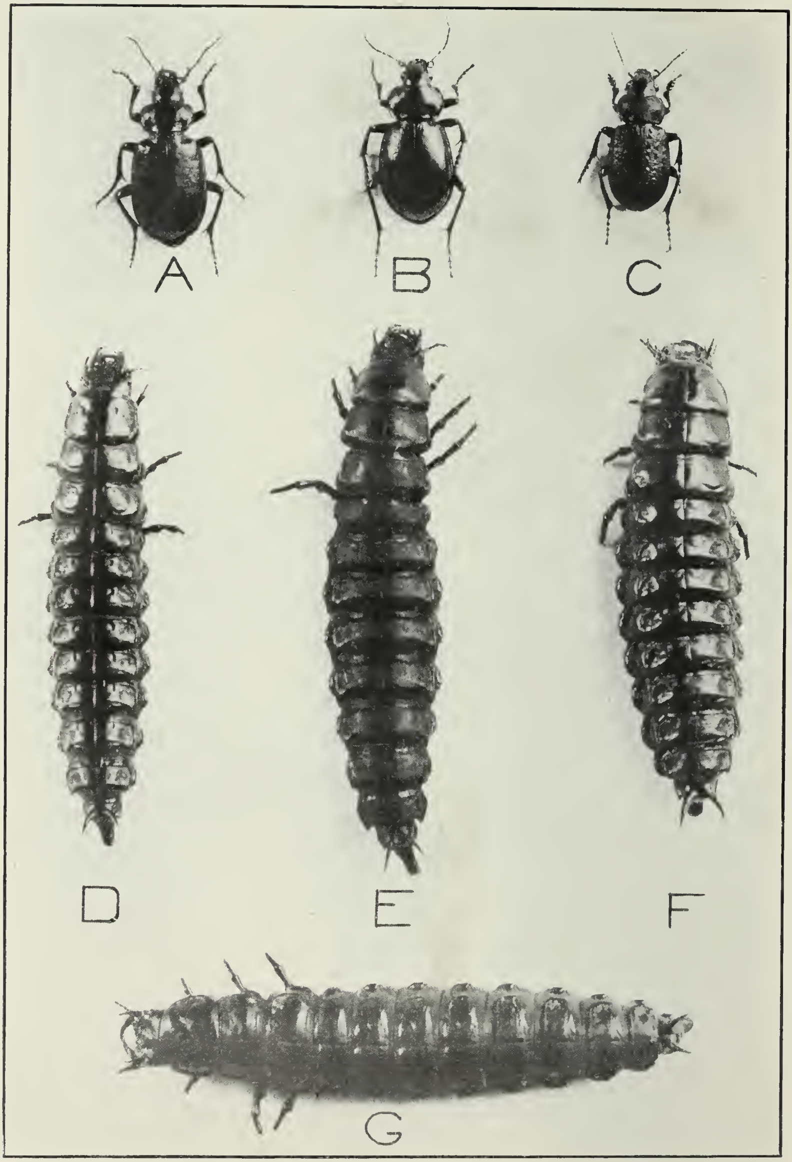
HABITS OF ADULTS.

Observations were made in 1911 and 1912 on the climbing habits of the adults, using the apparatus shown in Plate III. Adults were left inside the tin circle and were placed upon the bark of the tree several times between July 29 and August 2, 1911, and they would immediately descend. They proved to be rather clumsy and would fall in most cases before reaching the base of the tree. When the cage was visited the beetles were usually found buried in the earth at the base of the tree.



CALOSOMA RETICULATUM.

A.—Pupa, lateral view, ×4. *B*.—Same, dorsal view, ×4. *C*.—Same, ventral view, ×4. (Original.)



Species of Calosoma and their Larvæ.

A.—Calosoma obsoletum: Adult. *B.—Calosoma haydeni:* Adult. *C.—Calosoma cancellatum:* Adult. *D.—Calosoma obsoletum:* Third-stage larva. *E.—Calosoma haydeni:* Third-stage larva. *F.—Calosoma semilaeve:* Third-stage larva. *G.—Calosoma cancellatum:* Third-stage larva. *A–C*, about natural size; *D*, *F*, ×2½; *E*, ×2⅓; *G*, ×3. (Original.)

November 14, 1911, 6 males and 14 females were liberated in the beds of *Asparagus plumosus* in Mr. Elliott's greenhouse, Brighton, Mass., by the junior writer, and several of these were placed upon the leaves of the plants. They did not show any ability to climb the smooth stems of asparagus but merely clung to the leaves for a few minutes and then dropped. Mr. Dudley, upon liberating adults in the same place and under the same conditions, April 19, 21, and 30, 1912, states that several of the adults thoroughly demonstrated their ability to climb these asparagus stems. The stems twine about strings arranged for their support in an upright position and some of the beetles which were placed upon them about 5 feet from the ground ascended 15 feet or more. A few of the beetles climbed to the top of these plants and down again without falling.

The data secured on the latter dates seem to indicate that this species would fare well under the conditions that existed in this greenhouse, as the cutworms (*Noctua clandestina*) climb to the top of these plants at night and feed on the young terminals.

FOOD CONSUMED BY ADULTS.

Some daily feeding experiments were conducted in the laboratory with adults received from Texas, September 29, 1909, and these gave interesting results. Such food as larvæ and pupæ of *Hyphantria cunea*, puparia of *Varichaeta* sp., and larvæ of *Carpocapsa pomonella*, *Plodia interpunctella*, *Pontia rapae*, and *Tenebrio molitor* were offered and were consumed greedily.

TABLE 21.—*Feeding record of three pairs of Calosoma lugubre, 1910.*

Species of full-grown larvæ consumed.	First pair.[1]	Second pair.[2]	Third pair.[3]
Malacosoma americana	13	....	....
Porthetria dispar	115	95	67
Estigmene acraea	20	14	7
Hyphantria cunea	48	....	....
Total	196	109	74

[1] Male emerged June 30, female emerged June 15; pair ceased feeding Sept. 10.
[2] Male emerged June 23, female emerged July 3; pair ceased feeding Aug. 10.
[3] Male emerged June 30, female was unearthed July 17; record was discontinued Aug. 10.

None of the above beetles reproduced in 1909 but fertile eggs were secured from the two latter pairs in 1910. All of these beetles died at the end of that year.

Two pairs of adults received from Victoria, Texas, April 26, 1911, were fed in jars from that date until the female of the first pair died August 11, and the other ceased feeding to enter hibernation at that time. Both pairs reproduced during the season, which usually stimulates the feeding activity. The first pair (No. 4764) consumed 44 full-grown *Noctua clandestina* larvæ, 106 sixth-stage *Malacosoma americana*, 121 fourth to sixth stage *Porthetria dispar* and 16 full-grown *Estigmene acraea* caterpillars with 6 *P. dispar* pupæ, making a total of 293. The second pair (No. 4765) consumed 46 full-grown *N. clandestina* and 30 *E. acraea* larvæ; 113 sixth-stage *M. americana* and 136 fourth to sixth stage *P. dispar* caterpillars with 43 pupæ of the latter species, making a total of 368. These two records well demonstrate the feeding capacity of this species.

STARVATION OF ADULTS.

April 26, 1911, one pair of beetles was placed in a jar of moist earth without food to ascertain how long they would live under such conditions. The male died May 8 and the female May 26, the former having lived eight days and the latter one month after receipt, in addition to four or six days in transit, during which time no food was furnished.

The beetles had probably fed before being collected about April 20 and the experiment merely indicates that the species could exist for a short time until migration could take place if, for any reason, the food supply became scarce or exhausted in a given locality.

REPRODUCTION.

Several specimens received September 29, 1909, from San Antonio, Tex., were kept in a warm room and they remained active and fed; one pair until December 23. No reproduction was secured with this lot in 1909 and two out of three of the females that lived to emerge from hibernation in 1910 deposited 30 and 36 fertile eggs, respectively. None of this lot of beetles lived to emerge in the spring of 1911.

One pair of adults received from Victoria, Tex., April 26, 1911, was placed in a jar for rearing records and between May 24 and August 11 deposited 141 fertile eggs. This is the highest total for one female of this species recorded at the laboratory. Another female received at the same time as the foregoing deposited only 10 fertile eggs between May 31 and June 26, 1911. Sixteen males and 20 females were kept in jars and cages for reproduction in 1911 but only about 5 of these females reproduced.

LONGEVITY.

Some of the adults that were received from Texas in the fall of 1909 did not die until after entering hibernation in 1910–11. During the winter of 1909–10 they hibernated successfully in the laboratory cellar but died the next winter on being forced to hibernate outside. These adults were pupæ in the fall of 1908 or earlier and were slightly over two years old at the time of death. There is no doubt that they would live at least three years in a warm climate.

HIBERNATION.

Beetles received at the laboratory September 29, 1909 (seven pairs), and kept in a warm room between October 4 and December 23, buried themselves in cavities at the bottom of jars in which they were fed. After cavities were made the jars were filled with earth and transferred to the cellar where they remained until spring. The temperature of the cellar during the winter ordinarily ranged from 40° to 60° F. but on cold nights it dropped below 32°. The following spring the jars were transferred to outdoor cages. The beetles emerged between June 15 and July 2 and one male was removed from a cavity at the bottom of the jar as late as July 6 and a female on July 17. Most of them went as deep as was possible for hibernation, as the jars contained only about 4 inches of earth at the time the beetles entered.

Seven males and 11 females received from Texas in 1911 were placed in outdoor hibernation cages after they ceased feeding in the fall. From the same lot of beetles three males and five females hibernated in jars in the cellar. None of those put in outdoor cages lived to emerge in the spring of 1912, while two males of those placed in the cellar emerged May 10. The dead beetles were unearthed ½ to 6 inches below the surface. The two that emerged from the jars were at the bottom, or under 6 inches of earth.

The results of these experiments indicate that this species can not successfully hibernate under New England conditions.

COLONIES.

In the fall of 1911 and during the spring of 1912 over 150 beetles of this species were colonized in a florist's greenhouse at Brighton, Mass. This is the same house in which experiments were conducted with *Calosoma scrutator* as an enemy of cutworms. Although many visits were made it was impossible to determine that reproduction took place. At the close of the experiment, December, 1912, no evidence was secured to show that this species can live through one year under greenhouse conditions in the North.

No attempts were made to colonize adults of this species in the field in New England on account of their failure to survive the winter. Very little is known of their habits in the South and Central West, but judging from the large numbers collected at various times and shipped to the laboratory, and what has been learned of their habits, they must destroy large numbers of lepidopterous larvæ that feed on and near the ground.

THE EGG.

Twelve fresh eggs gave the following average measurements: Length, 4.1 mm.; width, 1.6 mm. They are of the same elliptical form, ordinarily tapering slightly toward one end, as are those of other species of the genus. White with a very faint yellowish tinge.

Notes secured in 1910 and 1911 indicated that eggs deposited the latter part of July and August required four and five days to hatch.

DESCRIPTION OF LARVA.

First stage.—Small, rather stout, tapering abruptly to anal end. Average length of 20 specimens, 7 mm.; width, 1.6 mm. Caudal appendages short, stout, angled about 45° from the body, bearing a few short spines. Color dull black on the dorsum, ventral plates grayish brown. Lateral and ventral plates bearing numerous short spines.

Second stage.—Stout, tapering same as in first stage. Average length of nine specimens, 13.2 mm.; width, 3.1 mm. Caudal appendages very short, not erect, curved downward beyond dorsal protuberance. Dorsal protuberance very short, not prominent, making an angle of 45° with appendages. Color shining black on the dorsum, ventral plates very dark brown to black.

Third stage.—Robust in form. Average length of 12 specimens, 19.5 mm.; width, 4.9 mm. Caudal appendages similar to those of second stage but stouter, dorsal protuberance presenting same aspect, acute and located about two-thirds the distance from base to tip. Color dull to shining black on dorsum, ventral plates dark brown to black. No reddish-brown patch on dorsum of last segment in second and third stages.

TIME REQUIRED TO COMPLETE LARVAL STAGES.

The length of time spent in the larval stages varies considerably; 4 to 7 days are required for the first stage, 5 to 7 for the second, and 12 to 15 for the third, to date of pupation; 26 to 30 are required from date of hatching to pupation. One larva closely observed in 1912 transformed to the different stages as follows: Eggs hatched June 11; time in first stage 3 days; in second, 8 days; in third to date of pupation, 15 days; a total of 26 days. The larva ceased feeding July 3 and pupated July 7. Thus 4 days were required in making a cavity and passing through the prepupal stage.

FOOD CONSUMED BY LARVÆ.

Eggs of this species hatch so late in the season that it is sometimes difficult to find food for the larvæ in New England, as caterpillars and pupæ of *Porthetria dispar* are not available at that time.

TABLE 22.—*Food eaten by larvæ of Calosoma lugubre, 1911.*

Varieties of food consumed.	4767-J.	4565-A.	4565-C.	4565-F.	4565-G.	4565-K.	4565-L.
Estigmene acraea larvæ, full-grown	7	3	2	1	3	3	2
Estigmene acraea pupæ		5	2	1			4
Porthetria dispar pupæ	5	1	4	1	5	12	3
Pontia rapae larvæ, full-grown	3		4	4	2	2	3
Pontia rapae pupæ	1	5					
Hyphantria cunea larvæ	2	7	3	9	19	5	4
Autographa brassicae larvæ, full-grown			2		3	4	1
Total	18	21	17	16	32	26	17

The larvæ hatched July 26 and August 6 and ceased feeding August 25, 26, and 28 and September 1, 2, and 12. Many of the larvæ and pupæ fed to them were small, as will be noted from Table 22, but the average number required to complete the growth of each was 21. Three similar records secured in 1912 averaged about the same, but larger caterpillars and pupæ were supplied during the time.

HABITS OF LARVÆ.

Data secured on the climbing habits of the larvæ of this species in the summer of 1911 gave negative results so far as they went.

Two first-stage larvæ were placed in the experiment (Pl. III) July 27 and 29. Neither attempted to climb the tree voluntarily but one when placed upon it crawled in and out of the crevices of the bark, neither ascending nor descending more than 2 inches before falling. It was again placed in the crotch of a limb and left for the night. It was found buried in the earth the following morning with no evidence that it had reached the food cage during the night. First-stage larvæ were repeatedly placed upon the tree with similar result.

Experiments with two second-stage larvæ indicated that they were able to climb very little.

August 8 a third-stage larva was placed upon the tree and in eight minutes climbed upward 2½ feet without stopping, then crawled under the bark. No further evidence of climbing was secured with third-stage larvæ. The actions of the larvæ in all stages were very similar to those of *Calosoma frigidum* and *C. inquisitor* and the indications are that they search for food on or near the ground.

PUPA.

Adults were reared from larvæ in 1911 and 1912 and notes were secured on the time spent in the pupal stage. From 2 larvæ that pupated September 4 and 12, 1911, 2 males issued as adults in 13 and 14 days, respectively. In 1912 two larvæ pupated July 7 and a female issued in seven days and a male in eight after pupation. The average mean temperature during the time the 1911 pupæ were in that stage, as taken from the Monthly Meteorological Summary issued from the United States Department of Agriculture Weather Bureau Office at Boston, Mass., was 63.5° F., while the average during the time the latter pair were pupæ in 1912 was 79° F. This accounts in a measure for the varying length of time spent in this stage. Seven and eight days are abnormally short pupal periods in comparison with those of other species of this genus.

The average length of the female pupa is 21.5 mm.; the width, 7.5 mm.; the male pupa is 17 mm. in length and 8.2 mm. in width.

Daily notes were made on the changes in appearance of three pupæ in 1911, and as these varied so little the notes on one (No. 4765–K) are given:

August 6. Egg hatched.

September 2. The larva ceased feeding and entered the earth for pupation.

September 12. Creamy white pupa observed in cavity at bottom of jar. Eyes light brown.

September 15. Eyes light brown, appendages and body still creamy white.

September 16. No noticeable change in pupa since the 15th.

September 18. Eyes changing to brownish-black. Aside from that no other noticeable changes in color of pupa.

September 19. Eyes black. No other definite change noted.

September 21. Eyes black, mandibles and tarsal claws brown. Anal segment of the abdomen and tibial joints also brown.

September 22. Mandibles brownish black, elytra yellowish brown.

September 23. Eyes and mandibles black, tibiæ and tibial joints almost black. Elytra yellowish brown. Tarsi light brown and claws dark brown.

September 24. Eyes, mandibles, and legs black, last segment of abdomen dark brown. Head and elytra yellowish brown; other segments of abdomen still light in color.

September 25. Male adult issued. External skeleton of beetle still soft, but has its natural color.

Thirteen days were required for completion of the pupal stage, and the beetle died later after being put into a hibernation cage.

EXPERIMENT TO DETERMINE RELATIVE PROPORTION OF CATERPILLARS CONSUMED DURING DAY AND NIGHT, 1912.

During the spring of 1912 two jars of adults, each containing two pairs, were used in this experiment. One jar (No. 5824–A) was supplied with food at 8 a. m. and the count of the number of cutworms (*Noctua clandestina*) eaten was taken at 5 p. m. and those remaining were removed until the following morning, when a new supply was added. Thirty-one full-grown cutworms were eaten during the days between May 4 and 24. Cutworms were supplied the other jar (No. 5824–B) at 5 p. m., when it was transferred to a dark closet until 8 a. m. The jar was then removed from the closet, the number of cutworms eaten noted, and those remaining were removed until 5 p. m. This operation was repeated from May 4 to 24, and 64 full-grown cutworms were consumed during the nights.

The experiment merely shows that these beetles feed either by day or by night, as circumstances may require. More cutworms were consumed by the beetles fed at night than by those fed during the day, but the probable reason was that the day-record jar was kept in the outdoor cage and the weather was quite cool, while the other jar was kept in a closet in the laboratory at night, where it was much warmer.

Similar experiments were tried with the larvæ of this species and it was found that they also feed during both day and night.

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Page 400. Original description of *Calosoma lugubre*.

1881–1884. Bates, H. W. Biologia Centrali-Americana, v. 1, pt. 1, 316 p., 13 pl.

Pages 21, 262. Note to the effect that *C. peregrinator* Guér. resembles more closely *C. lugubre* Lec. than *C. prominens* Lec.

1890. Bruner, L. Insects Injurious to Young Trees on Tree Claims. Univ. Nebr. Bul. 14 (Bul. Agr. Expt. Sta. Nebr., v. 3, art. 2), p. 83–149, 98 fig.

Page 117. Note of this species and *C. externum* being attracted to lights and their feeding upon May beetles.

CALOSOMA PALMERI Horn.

ORIGINAL DESCRIPTION.

Black, shining. Body feebly winged. Antennæ piceous, fourth joint slightly shorter than the fifth. Mandibles sparsely punctured with coarse and fine punctures intermixed. Head nearly smooth, with scarcely visible transverse wrinkles and very minute punctures. Thorax nearly twice as wide as long, base broader than the length and not emarginate, sides moderately arcuate and converging posteriorly, margin very narrow, not reflexed, hind angles obtuse, basal impressions moderately deep, median line very fine; surface extremely finely transversely wrinkled, and with very few punctures near the basal margin: elytra obovate, humeri broadly rounded, sides moderately arcuate, disc moderately convex, obsoletely substriate, striæ very indistinctly punctured, intervals 4–8–12 with very distinct larger punctures. Body beneath black, shining, smooth or obsoletely transversely wrinkled. Length .74 inch; 19 mm.

Male.—Anterior tarsi with three joints dilated and pubescent, fourth joint glabrous. Length 19 mm. Guadalupe Island, Cal.

Following this description,[1] Horn says:

This species should be referred to the same group with *triste*, etc. (Group iv., Lec. Proc. Acad. 1862, p. 53) from all the species of which it differs by the thorax being narrowed behind and the base narrower at the apex; the elytra are also obovate in the present species and oblong oval in all the others. The body in *Palmeri* is feebly winged, and in the others (except *Haydeni*) the wings are fully developed. In the latter species the elytra are connate, and I have been unable to detect traces of wings.

Numerous specimens were collected on Guadalupe Island by Dr. Edward Palmer, to whom I take great pleasure in dedicating it. Specimens were sent by me to my friend, M. Aug. Sallé, of Paris, who informs me that there is nothing in the fauna of Mexico with which it may be compared.

Aside from the locality just mentioned, this species occurs in California and Mexico.

CALOSOMA TRISTE Lec.

ORIGINAL DESCRIPTION.

Black, elytra very indistinctly striate and punctate, with three rows of larger impressed punctures.

Habitat: Territory of Missouri.

Ovate, somewhat elongated, with posterior somewhat convex, black. Head punctate anteriorly, minutely rugose posteriorly with impressions lightly marked, arched posteriorly. Thorax lightly corrugated and punctate, with punctures larger towards the base; emarginate anteriorly, sides rounded, lightly depressed posteriorly; posterior angles extending below the quite even base; no impressions anteriorly, lightly marked posteriorly; lines indistinct longitudinally, with basal impressions regular, deeply punctate. Elytra obsoletely punctate, and striate, with a few transverse grooves, quite indistinct; with small shallow punctures, also three impressed series of punctures on the interstices.

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[1] Horn, G. H. Notes on the coleopterous fauna of Guadalupe Island. *In* Trans. Amer. Ent. Soc., v. 5, p. 198–201 (p. 199), 1874–1876.

Calosoma indistinctum, Say, (which is described by Count Dejean under the name *luxatum*) quite agrees, but is larger and elongated. Striæ and elytral pits scarcely conspicuous; moreover the pits of *C. indistinctum* are blackish-blue.

DISTRIBUTION.

LeConte published the foregoing description in 1845, and since that time the species has been recorded from Arizona, Arkansas, California, Colorado, Kansas, Nebraska, and New Mexico. F. H. Snow reports having taken specimens at an altitude of 3,750 feet in Cochise County, Ariz. The species is known to occur in Mexico.

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Page 208. Original description of *C. triste* with habitat notes in the territory of Missouri.

1845. LeConte, J. L. Descriptions of new Coleopterous insects in the United States. *In* Boston Soc. Nat. Hist., v. 1, p. 201.

1877. Popenoe, E. A. A list of Kansas Coleoptera. *In* Trans. Kansas Acad, Sci. f. 1876, v. 5, p. 21–40.

Page 22. "Western Kansas."

CALOSOMA OBSOLETUM Say.

[Pl. XVII, *A*.]

(Syn.: *C. luxatum* Dej.)

ORIGINAL DESCRIPTION.

Brownish-black; elytra reticulated and with three series of impressed bluish spots.

Habitat: Arkansas.

Body brownish-black; mandibles rugose and convex on the superior surface; thorax obtusely and minutely rugose, impunctured; region of the posterior angle indented; an abbreviated impressed dorsal line; posterior angles rounded, extended backward a little beyond the basal line; elytra reticulate; longitudinal lines slightly impressed, not more dilated than the transverse ones, which are mostly continuous, their points of intersection marked by a puncture; three series of impressed bluish or violaceous obscure spots on each elytron; lateral margin in a certain light very obscurely purplish.

Length seven-tenths of an inch.

Found near the Rocky Mountains.

EARLY RECORDS AND DISTRIBUTION OF THE SPECIES.

This species was first described by Thomas Say in 1823. Dejean, in 1826, described *Calosoma luxatum*, which was later found by Dr. LeConte to be a synonym of *Calosoma obsoletum* Say.

It has been collected in the following States: Colorado, "Dakota," Kansas, Montana, Nebraska, New Mexico, Texas, and Utah. It has also been reported from the Northwest Territory in Canada.

COLLECTIONS AND SHIPMENTS.

The data included on this species were secured in New Mexico by members of the scientific staff under the cereal and forage insect investigations of this bureau in connection with the New Mexico range caterpillar (*Hemileuca oliviae* Ckll.). Mr. D. J. Caffrey planned and executed many of the experiments and, through the late Prof. F. M. Webster and Mr. W. R. Walton, acting in charge, Cereal and Forage

Insect Investigations, and Mr. V. L. Wildermuth, their notes were kindly placed at the writers' disposal.

October 11, 1915, there were received at Melrose Highlands, Mass., 11 males and 6 females living and 1 female dead from Mr. Caffrey. These were shipped from Maxwell, N. Mex. They were inclosed in jars and offered larvae of *P. rapae*, upon which some of them actively fed until November 1 before entering hibernation. They are still in hibernation at this writing (April, 1916). Many specimens were collected on the range between May and August, 1913 to 1915, and their habits studied in connection with the range caterpillar at Koehler, N. Mex.

FOOD CONSUMED BY ADULTS.

During the summers of 1913 and 1914 adults were collected on the range and one pair each inclosed in battery jars containing earth and records kept daily of the amount of caterpillars consumed and reproductive habits. The beetles were very numerous at Raton, N. Mex., in 1913, and 15 pairs were collected for rearing experiments. Several pairs fed from July 28 (date collected) until September 4 consumed 75, 65, 61, 57, 56, and 55 *Hemileuca oliviae* Ckll. larvæ, respectively, before being transferred to hibernation cages. The beetles proved themselves readily predacious on the above species, having averaged destroying approximately two caterpillars per day during the period. Those fed in confinement in 1914 devoured *H. oliviae* larvae from May 29 to September 5, proving predacious on this species throughout, but only to a slight extent after the middle of August. After that time the beetles were inactive and spent much of their time beneath the surface of the soil.

Both adults and their larvae were observed destroying the pupae of *H. oliviae* in their cocoons, but this particular stage of the host insect was destroyed more commonly by the beetle larvæ than by the adults.

REPRODUCTION AND HIBERNATION.

The females in confinement and under observation at the laboratory, Koehler, N. Mex., during 1914 deposited eggs, beginning the first week in June and ceasing about the first week in August. The eggs hatched in from six to nine days. One female, during this season, deposited 60 fertile eggs between June 8 and 17; one, 31; and another, 19. The latter female deposited eggs between July 13 and August 1. As is indicated by these records, the propagating and feeding season of the adults and feeding period of the larvæ extends over a long season, which approximates the growing period covered by the larval and pupal stages of *H. oliviae*.

The adults become more or less inactive after the middle of August to September 1 in the field and soon seek hibernation in the ground. Twenty-five beetles under observation, fed in cages in 1913, were transferred to hibernation cages September 4. The last of this lot entered the ground October 12. Their first appearance in the field was noted May 26, 1914, indicating the approximate time of first emergence. Those kept in jars containing 5 to 6 inches of loose soil at Melrose Highlands, Mass., fall of 1915, descended to bottom of jar to make cavities for hibernation.

The maximum length of life of adults of this species has not been definitely determined, but it is probable that they live two or three years.

FIELD OBSERVATIONS AND ECONOMIC IMPORTANCE.

Mr. C. N. Ainslie of this bureau under date of August 26, 1914, observed a number of adults of this species in alfalfa fields infested by *Loxostege* sp. at Friend, Nebr. The beetles were moving about rapidly, so he did not see them feeding. One specimen was taken for determination.

May 26, 1914, Mr. T. S. Wilson of this bureau collected the adults of this species on the ranges in New Mexico as early as May 26 in 1914. During the week of June 10 the specimens were showing up quite commonly. June 17 Mr. Caffrey states that the adults were noted to be present in abundance. Approximately 25 or 30 were seen in one-half hour. Hemileuca and Malacosoma larvæ were abundant in the vicinity. August 9 several of the beetles were observed on the slopes of Eagle Tail Mountain, N. Mex.

Mr. Walton and others observed the beetle larvæ feeding upon caterpillars and pupæ of *H. oliviae* in the field, the beetle larvæ seizing its prey in the usual manner for Calosoma in general and holding on until the caterpillar is subdued and a puncture effected with the mandibles. The body contents then ooze out in part and the beetle larva feeds until its appetite is satiated. In one instance, an adult beetle was noted feeding upon a male Hemileuca moth.

The beetles and their larvæ were found in practically all parts of a range infested with *H. oliviae* Ckll. but were noted more commonly near wooded areas. The adults and larvæ were noted feeding on pupæ of *H. oliviae* through the coarse meshes of the cocoon. These cocoons and pupæ were often located in weeds and grasses from 2 to 6 inches above ground and the fact that the beetle larvæ had found their prey in these situations indicates their ability to climb and their importance as an enemy of such a caterpillar pest.

Mr. H. F. Wickham conducted some investigations with this species along with *C. haydeni* Say by supplying both killed and living grasshoppers along with *H. oliviae* larvæ as food for the beetles to determine their preference with reference to accessibility of same. The results were similar for each species of beetle and are recorded under *C. haydeni* Say.

BRIEF DESCRIPTION OF LARVA.

First stage. Rather slender larva. Average length of five newly-hatched specimens that had been preserved in alcohol, 10 mm.; width, 1.9 mm.; color, black dorsally, ventral plates grayish-brown. Ventral plates ordinarily containing one and two long brown hairs and sometimes other shorter ones. Caudal appendages rather stout (1.3 mm. long), slender, projecting obliquely backward.

Second stage. Form similar to first stage. Average length of six specimens, 16.6 mm.; width, 3 mm. Caudal appendages bearing short acute protuberance dorsally beyond middle on each and curving slightly downward beyond these. Dorsum shining black and ventral plates dark brown in this stage.

Third stage (Pl. XVII, *D*). Rather slender larva. Average length of five almost mature specimens, 26 mm.; width, 4.6 mm. Caudal appendages rather stout (1.3 mm. long) and erect, curving backward after dorsal protuberance. Appendages widely separated at base, tapering to a point abruptly beyond dorsal protuberance, which is located about two-thirds the length of each appendage. Color shining black above, dark brown below. Ventral plates sparsely clothed with hairs. Anterior ventral plates 2 to 7, inclusive, oval in form, dilated in middle, sometimes notched posteriorly in the center, also containing a small median keel more prominent near the posterior margin. Posterior angles of anal segment narrow at base, slightly turned upward into a long blunt point with stout spine at apex. Posterior angles of tergite of penultimate segment projecting backward rather pointedly.

LARVAL RECORDS.

Many larvæ were reared in jelly glasses during 1913 and 1914 by Mr. D. J. Caffrey at the Koehler, N. Mex. laboratory, and both larvæ and pupæ of *H. oliviae* were consumed by them. Upon approaching maturity they were transferred to cages for pupation. Larvæ hatching June 10 and 16, respectively, remained active and fed until about July 2 to 10 before entering the ground for pupation. More Hemileuca larvæ are ordinarily destroyed at this season by each Calosoma larva when they are smaller than when the caterpillars are approaching maturity.

The average time required to pass the first larval stage was 6 days; for the second, 6, and for the third to date ceased feeding, 8. Additional to this, from 3 to 6 days are passed in the prepupal stage, thus totaling 20 to 26 days in the larval stages to period of pupation. The larva in the last few days makes an oblong-oval cell in the earth where the pupal stage is passed.

PUPA.

Two rather undersized specimens reared at Koehler, N. Mex., measured 15 mm. long and 7 mm. wide for the male and 18 mm. long and 8 mm. wide for the female. The head is folded back under the thorax, and wings folded over ventral side. The first five abdominal segments are clothed with very short hairs dorsally, dorsal surface of remaining segments smooth. Color, creamy-white.

Seven of the larvæ bred in New Mexico in 1914 went through the pupal stage and emerged as adults. From 3 to 6 days were passed in the prepupal stage and about 12 in the pupal. These larvæ like other species of the genus pupate in cavities in the earth.

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1826. Dejean, M. le Comte. Species général des Coléoptères de la collection de M. le Comte Dejean, T. II, p. 96.

Description of *C. luxatum* which Dr. Le Conte later threw into synonymy with *obsoletum* Say.

1877. Popenoe, E. A. A list of Kansas Coleoptera. Trans. Kans. Acad. Sci., vol. 5, p. 22.

Page 22. "Topeka and Lawrence."

CALOSOMA SEMILAEVE Lec.

ORIGINAL DESCRIPTION.

Black, without luster, face intricately punctate, with thorax intricately punctate, more heavily back of the middle; much wider than long, with sides quite rounded, margin somewhat reflexed at the base no less than at the apex, marked with two indentations on each side, with elytra finely punctate in series, punctures large on the anterior, interstices with imbricated grooves up to the middle.

Length 0.85. Single specimen, San Jose, Cal. I have found elytra of another at San Diego, Cal.

This species was described by Dr. Le Conte in 1851,[1] his type specimen being taken in San Jose, Cal. Collection data on the species in later years records it as occurring in many points in California south of San Francisco and in Camas, Idaho. Its range probably extends over a somewhat larger territory than is here represented.

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[1] Le Conte, J. L. Description of new species of Coleoptera from California. *In* Ann. Lyc. Nat. Hist. N. Y. f. 1851, v. 5, p. 125-216, 1852.

COLLECTIONS AND SHIPMENTS.

April 7 and 27, 1911, the late Mr. H. M. Russell of this bureau collected and shipped from Hollywood, Cal., 5 males and 8 females of this species to the laboratory at Melrose Highlands, Mass. They were collected under pea vines feeding upon larvæ of *Peridroma saucia* Hübn. Mr. P. H. Timberlake, also of this bureau, collected and mailed to the laboratory from Whittier, Cal., 1 female which was dead on arrival May 27, 1911. Mr. J. E. Graf collected in Compton, Cal., April 5 and 6, 1914, on low shrubbery 5 males and 12 females and forwarded them to Melrose Highlands, Mass. He reported them feeding on coleopterous and lepidopterous larvæ.

HABITS OF ADULTS.

June 9, 1911, one pair of beetles was liberated inside of the tin circle in the center of which stood a section of a white-oak tree (see Plate III). They first traveled around the circle for some time and did not attempt to climb. They were then placed upon the bark of the tree and immediately proceeded to descend. At another time when they were put upon the tree, they climbed slowly and steadily to the top. The female climbed out on a small twig one-eighth of an inch in diameter and 12 inches long, hanging on the underside. On reaching the end she fell.

These experiments and the findings of Mr. J. E. Graf cited under the previous subject (as having taken the beetles on low shrubbery) indicate that they do climb to some extent. Their habits compare in a measure to those of *C. frigidum* Kirby.

FOOD CONSUMED BY ADULTS.

Feeding records were kept of beetles confined in two battery jars during the spring and summer of 1911. May 3 the beetles were received from Hollywood, Cal., and were fed cutworms (*Noctua clandestina* Harr.) until June 27. Two males and 5 females were placed in the two jars and 37 fifth and sixth stage *P. dispar* caterpillars and pupæ were consumed in about 15 days after the records were started. Two males and 2 females died between July 7 and 18 and the remaining females ceased feeding by August 2 and descended in the jars for hibernation.

One pair of adults from California, April, 1914, were offered *N. clandestina* larvæ after receipt, of which they consumed from 7 to 12 per day for a period of 3 weeks. *M. americana* larvæ were later consumed until about June 1, when the beetles began to remain inactive at the bottom of the jar.

The beetles were most active during April and May, at which time it was difficult to secure sufficient caterpillars for food.

REPRODUCTION AND HIBERNATION.

Three males and 8 females were kept under observation in three jars at the laboratory during the summer of 1911. All of these died during the summer except 3 females that entered hibernation about

July 19 and August 3. No eggs were secured from any of the females notwithstanding the fact that the collector saw one pair in copulation April 27 at Hollywood, Cal., the day they were shipped.

The three females that entered hibernation in outdoor cages during the summer of 1911 were found dead and dismembered 3 and 4 inches below the surface of the earth in the spring of 1912. It is very probable that this species is not adapted to withstand New England winters.

Of the lot of adults received from California April, 1914, two pairs were enclosed in one jar in which eggs were found May 15 and June 5. One of these females died before eggs were deposited, and 69 larvæ hatched as a total from one female. June 18 a few infertile eggs were deposited on the surface of the earth in a jar which contained 1 male and 4 females at the time.

None of the adults lived to enter hibernation that fall.

EGG.

Nine eggs that had been preserved in alcohol averaged 4 mm. in length and 1.7 mm. in width. Color white, form elliptical, tapering slightly toward anal end in those containing fully developed embryo.

Sixty-nine eggs deposited by one female in 1914 between May 11 and June 5 hatched in from 6 to 13 days.

BRIEF DESCRIPTION OF LARVA.

First stage.—Small robust larva. Average length of 6 newly-hatched specimens that had been preserved in alcohol, 8 mm.; width, 2.2 mm. Color dark brown dorsally, ventral plates grayish brown. Ventral and lateral plates especially thickly set with long brownish hairs. Caudal appendages (1.3 mm. long) very slender.

Second stage.—Form similar to first stage. Average length of 3 specimens (almost ready to molt) 18.5 mm., width 3.2 mm. Caudal appendages rather long and pointed with several protuberances bearing spines, the middle dorsal being slightly more prominent than others. Color of dorsum dark brown to black, ventral plates brown.

Third stage (Pl. XVII, *F*).—Short robust larva. Average length of 4 specimens 24.5 mm., width 5.7 mm. Caudal appendages rather long (1.8 mm.), diminishing abruptly in size after middle. Dorsal protuberance on middle of each appendage rather long, acute, extending backward, parallel with caudal appendage. Appendages show slight curve downward beyond middle, tapering to a short point. Color shining black above, grayish brown below. Ventral plates thickly set with hairs, regular in outline. Anterior ventral plates on abdominal segments 2 to 7, inclusive, oval in form and somewhat dilated, without regular marginal notches. Posterior median plates rectangular in form and outer ventral plates on 3d to 7th abdominal segments oval. Posterior angles of anal segment narrow at base, projecting straight backward into a long blunt point with stout spine at apex.

LARVAL RECORDS.

Many larvæ were reared in individual jars during 1914 and were fed *M. americana* larvæ which were very easy to obtain during May and June. It was estimated that from 20 to 35 large caterpillars were destroyed by each beetle larva before maturity, as actual counts were not made in connection with this species.

The larvæ are active and feed over a period of from 18 to 25 days, or an average of 23. Time required to complete the various stages in an outdoor vivarium at the laboratory, as averaged from 7 specimens, was 5 days for the first, 4 for the second, and 14 for the third up to the time the larvæ ceased feeding. An additional period of from 4 to 6 days elapsed before the larvæ pupated.

HABITS OF LARVÆ.

During June, 1914, some observations were made on the climbing habits of the larvæ at the laboratory (Plate III) and it was found that the very young individuals were inclined to do this to some extent, one specimen having climbed up the white oak post 6 feet, then out on stovepipe wire and back to post before falling. Second-stage larvæ did not show an equal ability in this respect, and third-stage larvæ were not tried, owing to a limited amount of material.

It is rather difficult to estimate from these limited observations to what extent this habit prevails in the field, which is indicated by the habits of the host insect upon which this predator most commonly feeds.

PUPA.

Two male pupæ were preserved in alcohol from the rearings of 1914, the average measurements of which were 18.5 mm. in length and 8.2 mm. in width. Several larvæ pupated and were reared through to maturity.

Notes were made on the changes of color and development of one pupa found in cavity at bottom of jar July 5 and transferred to surface of earth. The pupa was creamy white, the mouth parts and tarsi after about five days beginning to turn brown. This color darkened with age and later the tibiæ began to show brown. After nine days the thorax and abdomen had changed gradually to brownish black. Legs brownish black at that period. July 18, the pupa died just as it was about to mature.

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CALOSOMA SIMPLEX Lec.

ORIGINAL DESCRIPTION.

Black, subopaque. Head and prothorax finely rugose and punctulate, the latter more than twice as wide as long; sides strongly margined, rounded in front, oblique behind, more widely reflexed towards the base; base bisinuate, broadly rounded at the middle, hind angles distinctly prolonged, broadly rounded; basal impressions large and deep; dorsal line fine. Elytra slightly wider than the prothorax, oblong, oval, convex towards the sides, which are narrowly margined towards the base and more widely so along the sides; near the base are seen four small acute teeth, as in our allied species; striæ not impressed, composed of extremely fine punctures; the punctures of the three dorsal rows are also small and not conspicuous; interspaces alutaceous, not distinctly rugose. Tibiæ straight.

Length 20.5 mm. Middle California, one male.

DISTRIBUTION.

This species was described by LeConte in 1879,[1] the type specimen, which was a male, having been taken in California. It has been reported from Arizona, California, Colorado, and Texas. It has also been taken in Mexico.

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[1] LeConte, J. L. Description of a new species of Calosoma. *In* Bul. Brooklyn Ent. Soc., v. 1, no. 8, p. 61–66, 1878.

CALOSOMA HAYDENI Horn.

[Pl. XVII, *B*.]

ORIGINAL DESCRIPTION.

The above name is proposed for a species in which the first three joints of the anterior tarsi of the male are spongy pubescent beneath, the base of the thorax truncate. It is therefore allied to our *triste* and *obsoletum*, but differing from them in having the elytra connate and body apterous. The head is large, as in *triste*, and the frontal impressions deep, rather finely punctured and wrinkled; vertex with but few punctures, occiput smooth. Thorax as in *triste*, but with the basal impression deeper and the lateral margins at base more strongly reflexed, nearly as much as in *semilaeve*. Disc with distinct coriaceous sculpture and feeble median line, margins coarsely but distantly punctured, becoming more dense near the hind angles and basal region. Elytra elongate oval, humeri strongly rounded, and as distinctly margined as the sides. Surface very convex in both directions and with striae of fine distinct punctures feebly impressed. Basal region with distant submuricate punctures. Margins distinctly muricately punctured, more dense at the humeral region, almost disappearing at the apex. Metathoracic parapleurae and sides of abdomen with coarse punctures. Its color above and beneath is shining black.

Length 0.84 inch; 22 mm.

Collected in southern Colorado by C. Thomas, of the U. S. Geological Survey, under Dr. F. V. Hayden.

DISTRIBUTION.

This species was described by Dr. Horn in 1870.[1] The type specimen was collected in southern Colorado. There are also other later reports of its being taken in Colorado, Arizona, and New Mexico.

COLLECTIONS AND SHIPMENTS.

The data included on this species were secured in New Mexico by members of the scientific staff under the Cereal and Forage Insect Investigations of this Bureau in connection with the New Mexico Range Caterpillar (*Hemileuca oliviae* Ckll.). Mr. D. J. Caffrey with the assistance of others conducted the life-history studies and through the late Prof. F. M. Webster and Mr. W. R. Walton, the notes were secured for publication here.

October 16, 1915, there were received at Melrose Highlands, Mass., from Mr. Caffrey at Maxwell, N. Mex., 7 males and 5 females, living. These were packed in damp sphagnum moss and arrived in good condition. They were placed in battery jars and fed larvæ of *P. rapae*. One pair remained more or less active until November 2 in Massachusetts and consumed 22 of the above larvæ before entering hibernation. They are still in hibernation at this writing (April, 1916).

FOOD CONSUMED BY ADULTS.

July 28, 1913, 2 males and 1 female were collected in the field and enclosed in a battery jar. They were offered plenty of *H. oliviae* larvæ and pupæ during the season of which they consumed 114 of the larvæ up to September 13. They were offered the pupæ after this date but refused. Weather conditions changed to cold and windy and the beetles sought hibernation soon after. In another jar containing the same number of adults, 102 Hemileuca larvæ and no pupæ were consumed. The beetles in cages in 1914 proved predacious on *H. oliviae* larvæ and fed from June 8 to September 3, the number destroyed each day gradually decreasing until toward the end of

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[1] Trans. Amer. Ent. Soc., Vol. 3, 1870, p. 69.

August feeding practically ceased, the beetles spending most of their time in the earth in the jar.

Mr. H. F. Wickam conducted cage experiments at Koehler, N. Mex., in August, 1914, to determine if the beetles would kill and eat grasshoppers and *H. oliviae* caterpillars and if preference was shown. The experiment was started August 10 and both varieties of living prey were supplied. In one cage under observation 33 days, 33 large *H. oliviae* larvæ and two grasshoppers were killed and eaten and in another cage containing 3 beetles under observation 15 days, 6 caterpillars and 1 grasshopper were killed and eaten. Some contrasting experiments were conducted at the time where killed grasshoppers were supplied the beetles with living *H. oliviae* caterpillars and as a result many more of the former were consumed than of the latter. Dead caterpillars were not eaten so readily as living. These experiments indicate that accessibility to a particular host is the important factor in the partial control by a predator. Practically the same results were secured in like experiments with *C. obsoletum* Say.

REPRODUCTION AND HIBERNATION.

Two males and 1 female in breeding jar from July 28 to September 13, 1913, deposited at least 6 eggs, 3 of which hatched. Copulation was observed several times during the season. In another jar containing the same number of adults, 18 eggs were deposited, 15 of which hatched. The first eggs were deposited by beetles in confinement in 1914 on June 9 and the last August 4. In one cage containing more than one female, 156 larvæ hatched and in another 162 hatched. The time in the egg stage varied from 7 to 12 days.

The first adults issued from hibernation in New Mexico in 1914 on or before June 5 and adults were seen in the field up to September 2 and even October 10, the latter dates indicating the late periods of entering hibernation. One beetle remained on the surface of the earth in a jar at Melrose Highlands, Mass., as late as October 20, 1915. They went into the soft earth to the bottom of the jar, a depth of 5 to 6 inches, for hibernation.

The maximum length of life of adults of this species has not yet been determined but they undoubtedly live 2 years or more.

FIELD OBSERVATIONS AND ECONOMIC IMPORTANCE.

June 5, 1914, one female was collected near Dorsey Reservoir and on the same date Messrs. W. R. McConnell and T. S. Wilson collected a large number to the south of Koehler, N. Mex. The beetles were found under rubbish, in the bed of a dry creek. Hemileuca larvæ were present in the vicinity but were not very numerous. June 28, 1915, Mr. D. J. Caffrey observed north of Maxwell, N. Mex., a female of this species feeding upon a second-stage larva of *H. oliviae* Ckll. and in the region of Chico on September 2 observed a larva of this species or *obsoletum* Say feeding upon a partly formed pupa of the same host.

The adults were observed in the field in New Mexico in common with *C. obsoletum* Say at periods from June 5 to about October 10, always associated with its host, *H. oliviae* Ckll., and apparently accomplishing a great deal in the natural control of the above pest. Mr. Caffrey observed the beetle larvæ feeding upon Hemileuca pupæ.

Generally the anal end of the beetle larva was seen protruding through the meshes of the Hemileuca cocoon which indicated what was happening inside. Upon closer examination it was found that the Hemileuca pupa was being destroyed. These pupæ attacked were located 5 to 6 inches above ground, generally in Gutierrezia plants, demonstrating the ability of the larvæ to climb for their prey. Adults were also noted feeding upon the pupæ to a small extent.

BRIEF DESCRIPTION OF LARVA.

First stage.—Long, rather slender larva. Average length of 5 newly hatched specimens that had been preserved in alcohol, 10.3 mm.; width, 2.1 mm. In very young larvæ head and thorax dull black and abdomen brownish-black above and grayish-brown below. Ventral plates ordinarily containing from 1 to 3 long brown hairs and sometimes other shorter ones. Caudal appendages long (2 mm.), straight, projecting obliquely backward.

Second stage.—Form similar to first stage. Average length of six fairly large specimens, 19.6 mm.; width, 3.2 mm. Caudal appendages long, straight, bearing short, acute protuberance dorsally in middle. Appendages continuing almost straight after dorsal protuberance. Dorsum dull brownish-black, ventral plates brown.

Third stage (Pl. XVII, *E*).—Long slender larva. Average length of five almost mature specimens, 31 mm.; width, 5 mm. Caudal appendages long (2 mm.), rather slender, curving slightly backward up to short, acute dorsal protuberance located in middle and straight beyond these. Color dull to shining black above, very dark brown below. Ventral plates rather thickly clothed with short hairs. Anterior ventral plates 2 to 7, inclusive, oval in form with slight dilations irregularly occurring in middle of anterior margins. Anterior ventral plates also without median keel as appears occasionally in *obsoletum*. Posterior median plates in well fed larvæ without broad line of separation between the two plates, apparently joined, especially on 6th and 7th abdominal segments. Inner angles of all these plates square, outer rounded, with outer margins containing broad deep notch in middle. Posterior angles of anal segment short, obtuse, bearing spine at apex. Posterior angles of tergite of penultimate segment also obtuse in form, almost truncate at apices.

LARVAL RECORDS.

Some feeding records were secured with larvæ of this species by Mr. Caffrey in August, 1913, at Koehler, N. Mex. At that time, *H. oliviae* larvæ which were offered were almost full-grown and in most cases only a small number were required before maturity. Two to three caterpillars were consumed in the first larval stage, 2 in the second, and 4 to 6 in the third, or a total of about 10 to 12. The beetle larvæ were transferred from small containers for pupation upon approaching maturity and the feeding record closed, otherwise it is probable that slightly more would have been destroyed. These beetle larvæ were active and fed from about August 13 to August 26.

The average time required to pass the first larval stage was 6 days; for the second 4.5, and for the third to date ceased feeding, 8. Additional to this, from 3 to 5 days are passed in the prepupal stage, thus totaling 22 to 25 days in the larval stages to period of pupation. The larva in the last few days of its activity makes an oblong-oval cell in the earth for pupation, as is the habit with other species of the genus.

PUPA.

Two rather undersized specimens reared at Koehler, N. Mex., measured 17 and 15 mm. in length and 7.5 and 7 mm. in width, respectively. These specimens were somewhat broken in shipment to Melrose Highlands, Mass. The first five abdominal segments are clothed with short hairs dorsally while the remainder of the segments are smooth. General appearance same as other species of the genus.

Several of the larvæ reared in 1914 lived to pupate and adults were secured. Pupation took place in a cavity in the earth which was usually formed at the bottom of a glass jar where observations could be made on the transformations. The specimens studied pupated in July and August. Eleven to fourteen days were passed in this stage.

July 11, one pupa was noted in cavity, light yellow in color with dark brown eyes. July 25, 10 a. m., the beetle was fully formed, body, wings, and femora still white; eyes, tibiæ, and tarsi black; 1.30 p. m., the immature beetle all black except central portion of body; 6.30 p. m., beetle all black and fully formed but occupying pupal cavity.

July 26, a female emerged from the cavity. Other young beetles emerged in breeding experiments at this time instead of remaining in the same cavity for hibernation. Some of the species reared at Melrose Highlands, Mass., namely, *calidum*, have this habit to some extent.

CALOSOMA TRISTOIDES Fall.

ORIGINAL DESCRIPTION.

This name is proposed for a form occurring in our extreme southwestern region, which is closely related to but quite surely distinct from *triste* of the west central states. As compared with Kansas specimens of *triste*, in my collection *tristoides* differs in the much finer punctures of the elytral series, these becoming very minute posteriorly, and in the usually well developed greenish lustre of the elytral margins. The sides and basal impressions of the prothorax also show more or less of the metallic lustre in many specimens, but in some it is barely perceptible. The coarser serial punctures of intervals 4, 8, 12 are green as in *triste*, but in the latter species the side margins of the body are scarcely at all so. In the type series of three examples of *triste* in the LeConte collection the sides of the prothorax are evenly rounded and the elytra are parallel in both sexes. In *tristoides* the prothorax exhibits considerable inconstancy in both relative and actual dimensions, the width varying from 1.53 to 1.72 times the length, the sides either evenly rounded or evidently straighter posteriorly; the basal sinuations are also variable in depth. The elytra are quite uniformly parallel in the male and a little wider posteriorly in the female. It is, however, very probable that a good series of *triste*, or for that matter of any other species of Calosoma, would show similar variability. In length *tristoides* ranges from 22 to 24 mm., width 9.4–10.2 mm. The length given for *triste* in LeConte's table is 18 mm.

Tristoides is based on a good series taken by Mr. Ricksecker at or near San Diego, Cal. A single specimen from an unknown source and simply labeled "Cal." has stood for years in my collection as *triste*. There is a single example from "Cal." in the LeConte collection placed near but not in line with his specimens of *triste* and bearing a "?" label.

This species was described by Mr. H. C. Fall in 1910[1] from specimens taken at or near San Diego, Cal., by Mr. Ricksecker. The writers have examined two female specimens collected by Mr. W. M. Mann, at Pachuca, Hidalgo, Mexico. Mr. H. W. Wenzel, of Philadelphia, has kindly furnished a cotype of this species for examination and study.

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[1] Fall, H. C. Miscellaneous notes and descriptions of North American Coleoptera. *In* Trans. Amer. Ent. Soc., v. 36, p. 89–197 (p. 92), 1910.

CALOSOMA CALIDUM (Fab.).

(Syn.: *Calosoma lepidum* Lec.)

ORIGINAL DESCRIPTION.

[Translation.]

Carabus, wingless, black, elytra crenate-striate and with hollowed out golden punctures in triple row.

Habitat in America.

Related to *Carabus hortensis*, but with elytra by no means as smooth, interstices between the golden punctured striæ very elevated, crenate. Antennæ reddish at the apex.

EARLY RECORDS OF THE SPECIES.

This species was first described by Fabricius in 1775 and was given a place in his other writings until 1801. During the latter year the genus Carabus was subdivided into Carabus and Calosoma and this species was included in the latter group. Latreille, Say, Dejean, and Kirby gave descriptions of the species and notes as to its habitat. The latter in 1837 wrote that "it is very common in all parts of North America."

LeConte, in 1845, described a new species as *Calosoma lepidum* from the Territory of Missouri, but later writers and collectors seemed to have ignored it. There is no record of the species in any of the public collections of the United States save the single type specimen in the Museum of Comparative Zoology, Cambridge, Mass. An examination shows that this specimen should be referred to *C. calidum*, therefore *lepidum* is regarded as a synonym.

Glover, Fitch, Walsh, and Riley have all published brief notes on this species. F. G. Schaupp in 1882 made a biological study of the species and described the larva. In 1896 and 1897 the senior writer made further studies into the life history of the species and described the larval stages.

Various other writers, namely, Comstock, Fletcher, Lintner, Packard, Forbes, Bruner, and others have published many interesting notes on the feeding habits of the beetles and their larvæ, together with their occurrence in different parts of the continent.

DISTRIBUTION.

This species is found in Colorado, Connecticut, Delaware, District of Columbia, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Dakota, Tennessee, Vermont, Virginia, and Wisconsin. It has also been reported from Alberta, Nova Scotia, Ontario, and Quebec, Canada.

SHIPMENTS.

November 6, 1911, two males and one female were removed from hibernation cages, packed with damp sphagnum moss in perforated tin boxes, which were inclosed in a tube and mailed to Mr. E. M. Ehrhorn, Honolulu, Hawaii. On December 1 he wrote that the beetles reached him in fine condition. This was the first experiment, to the writer's knowledge, in shipping Calosoma beetles long distances while dormant. It was successful, however, in this small attempt, and could be tried on a large scale when many specimens are to be transferred from one country to another.

A further attempt was made in 1912 to forward adults of this species to Mr. Ehrhorn, and small shipments were made by mail May 22, June 6, and June 17. A total of 16 males and 23 females, all alive, were sent, and 21 of the 39 specimens reached Honolulu alive. They were packed singly in pill boxes with damp sphagnum moss, but the moss had dried out in many cases on arrival, according to information received. The beetles were liberated in the foothills to prey upon cutworms which were very numerous in the islands. The genera Calosoma and Carabus are unrepresented there, which partly explains the annual abundance of cutworms. *C. calidum* in both the larval and adult stages seems perfectly adapted to prey upon cutworms and favorable results are bound to ensue if the species can be successfully established.

HABITS OF ADULTS.

May 31, 1911, a lively male was placed upon a section of a white oak tree set up in an outdoor cage, in order to make some observations on its climbing habits. (Pl. III.) It climbed very slowly and awkwardly, each time making more than one attempt before firmly gripping the bark and moving upward. The specimen on trial did not appear at all sure-footed, falling often and as soon as on level ground would move very rapidly.

Mr. Mosher says that he has repeatedly seen adults of this species under burlaps feeding upon caterpillars of *Porthetria dispar*, but has not seen them higher on trees than where burlaps are usually placed. They are sometimes collected on tree trunks at sugar when "sugaring" for moths.

REPRODUCTION.

The highest number of eggs deposited by one female in a single season was 74, but another deposited 61. Close records were kept of a few pairs of beetles in the years 1909, 1910, and 1911, with special reference to their capacity for reproduction. Only a part of the females reproduced each year they were in captivity, and the number of eggs that were deposited varied from 16 to 61 per female. One pair of beetles was observed in copulation May 20, 27, and 29, and June 2, 21, and 22, but only 16 eggs were deposited. It is probable that this species resembles *sycophanta* in that some of the females live an entire season without laying eggs.

LONGEVITY.

Most of the specimens of *Calosoma calidum* collected in New England and confined in jars have not lived longer than one year. One female, however, which was collected August 20, 1909, lived until June 5, 1911. One male was placed in the jar with the female shortly after she was collected, but died during the following fall or winter. Another male, added in the spring of 1910 and collected the same year, lived until after the female died in 1911. No eggs were deposited by the female in 1909 or 1910, but 22 fertile eggs were deposited in the spring of 1911. As the female was collected late in the summer (Aug. 20) it is both possible and probable that it was a recently issued adult, as it is shown below under "Food consumed by adults" that the beetles often come to the surface of the earth and wander about in search of food after emerging from the pupa. The male that was added in the spring of 1910 was a pupa in the summer of 1909 or earlier; therefore it also lived about two years or more.

The data at hand on this species will not permit the statement that the adults live longer than two years. There is a possibility, however, that they live three years, or as long as *sycophanta*, *inquisitor*, *wilcoxi*, and others.

FOOD CONSUMED BY ADULTS.

In Table 23 are given the best records secured on the food consumed by this species.

TABLE 23.—*Feeding records of 3 pairs of Calosoma calidum, 1909, 1910, and 1911.*

Pair No.	Year.	Feeding record started.	Ceased feeding.	*Noctua clandestina* (sixth stage).	*Malacosoma americana* (fifth and sixth stages).	*Porthetria dispar* (fifth and sixth stages).	Total.
1797	1909	June 13	July 1[1]	....	130	69	199
2879	1910	May 4	July 29[2]	13	183	[3] 121	[3] 317
5069	1911	June 6	July 26[1]	....	57	[3] 104	[3] 161

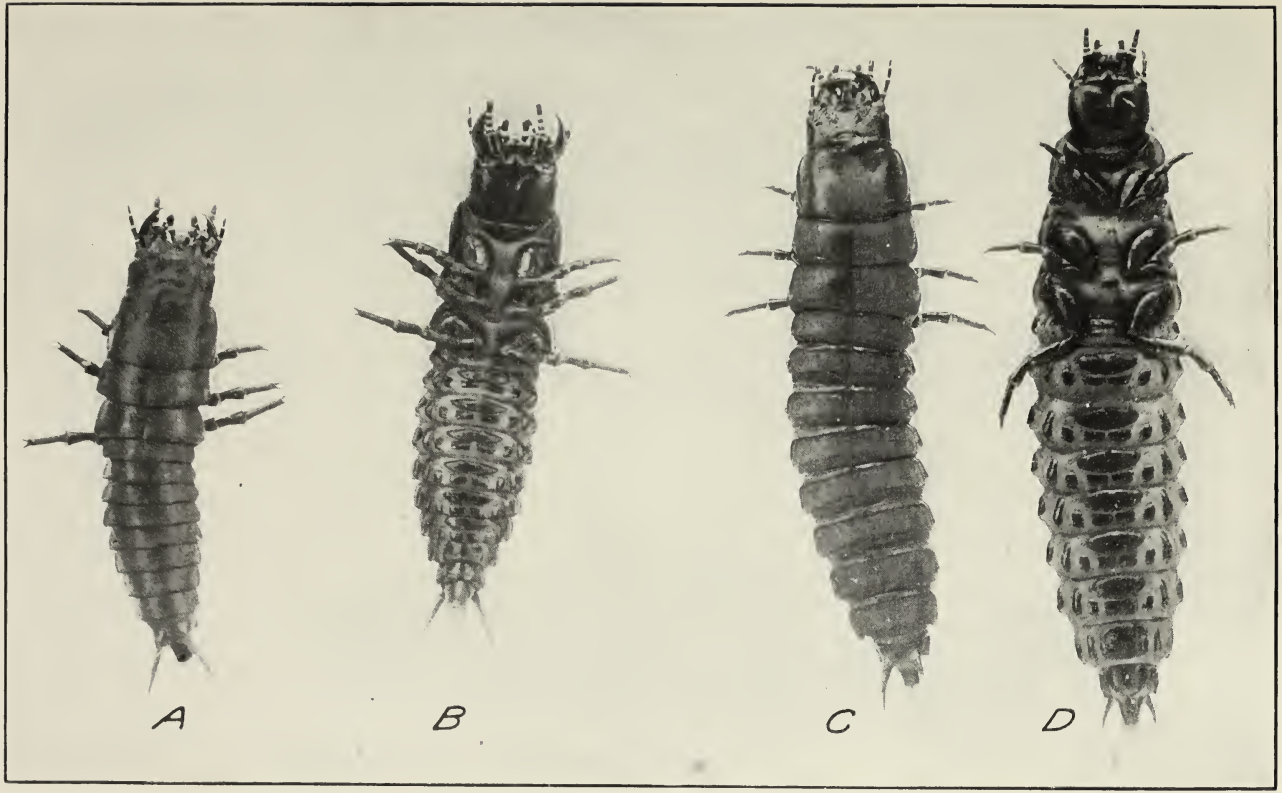
[1] Female died, record discontinued.
[2] Pair entered hibernation.
[3] Besides one pupa.

Each of the pairs cited in Table 23 reproduced; the first female deposited 59 eggs, the second 16, and the third 24. The record of the 1909 pair is incomplete as the male was not collected until June 13, on which date the record was started, and the female died July 1, thereby shortening the active feeding period by about two months. The average number of large-sized caterpillars devoured by each pair was 226. The period of emergence from hibernation for this species is from April 15 to May 15, and the period of entering hibernation August 1 to 15, leaving an active period extending over approximately three months.

One female reared from the egg in 1909 came to the surface and devoured two sixth-stage caterpillars of *Porthetria dispar* and 70 third and fourth stage caterpillars of *Hyphantria cunea* before reentering the ground for hibernation on September 11. Two males and one female, reared from eggs in 1910, came to the surface of the earth in from one to nine days after transformation from the pupæ. The males ate 21 and 28 sixth-stage caterpillars of *P. dispar*, respectively, before reentering hibernation August 4. The female ate three caterpillars and died.

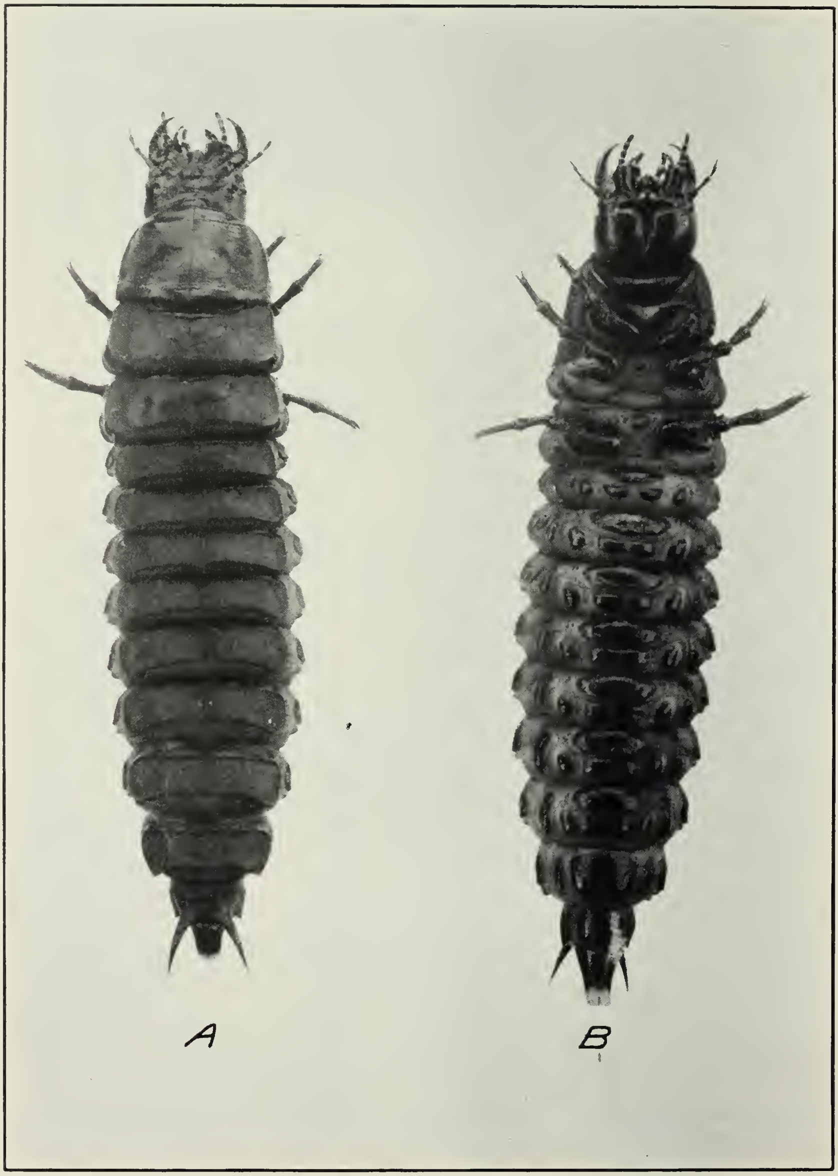
All the specimens of this species reared in jars or cages during 1909, 1910, and 1911 came to the surface in search of food in a few days after transformation from the pupæ. Young adults of *Calosoma calidum* are so voracious that sometimes after coming on the surface they attack one another, if caterpillars are not available.

The habit of feeding during the first fall after entering the adult stage is rather uncommon with other species of Calosoma that have been studied in detail by the writers.



CALOSOMA CALIDUM.

A.—First-stage larva, dorsal view, ×6. *B*.—Same, ventral view, ×6. *C*.—Second-stage larva, dorsal view, ×5. *D*. Same, ventral view, ×5. (Original.)



CALOSOMA CALIDUM.

A.—Third-stage larva, dorsal view, ×4. *B.*—Same, ventral view, ×4. (Original.)

HIBERNATION.

One pair of beetles entered hibernation August 30 and emerged May 17 and 26, 1910, and the average date of entering for 10 adults in 1910 was August 1. Only one pair of these beetles lived, and they emerged May 15, 1911. During normal seasons in Massachusetts this species enters hibernation during the first half of August and emerges between April 15 and May 15.

The average depth in the ground to which these beetles go to hibernate is about 2 inches.

THE EGG.

The egg is white. Measurements of 12 fresh eggs in 1910 gave an average length of 5.8 mm. and a width of 2.5 mm. The adults of *C. calidum* are much smaller than *scrutator* or *sycophanta*, but the eggs run somewhat larger than those of either species. They have the same general form (elliptical) as those of the species just mentioned and taper slightly toward one end.

The average number of days required to hatch 59 eggs deposited by one female between June 15 and June 28, 1909, was 4½. The temperature at that time was very favorable for the acceleration of hatching, the maximum ranging between 80° and 90° F. One hundred and ninety-nine fertile eggs deposited by several females between May 22 and August 2 required an average of nine days to hatch. Most of the deposition took place during the month of June, and nine days is about the normal time spent in the egg stage by this species.

DESCRIPTION OF LARVA.[1]

First stage (Pl. XVIII, *A*, *B*).—Length, 8 mm.; width, 2 mm. at third thoracic segment. Form ellipsoidal, tapering more gradually toward the last segment than in the corresponding stage of *C. frigidum*. General color of the body and mouth parts dull black, not shining. Head large, as long as wide, dorsal surface flattened; palpi prominent, longer than antennæ. Posterior margin of the head somewhat emarginate at the center. First thoracic segment as long as the two following, slightly wider than the head and edges produced laterally. All the body segments except the last are truncate behind, and bear a prominent impressed dorsal line. Caudal appendages present, simple, and provided with numerous spines.

Ventral portion of the body nearly pure white, but it is profusely covered with small black chitinous plates. Spiracles nine, black, circular, and arranged just below the lateral edges of the dorsal plates. Anal proleg moderately stout. After feeding for a week the larvæ molted.

Second stage (Pl. XVIII, *C*, *D*).—Soon after molting the larvæ become black and measure 18 mm. in length. Body somewhat stouter than in preceding stage. Head longer than wide, emarginate behind. Prothorax wider than the head. Dorsal line quite prominent. Abdominal segments truncate and slightly produced laterally. The second molt occurred at the end of a week.

Third stage (Pl. XIX, *A*, *B*).—The following description was not made until the larva was almost ready to pupate. Length, 30 mm. Color, dull black. Head of medium size, flattened, truncate behind. Clypeus slightly broader in front than in *C. frigidum*. Strongly bilobed. Suture between clypeus and epicranium subobsolete. Mandibles stout, the large tooth near the base being deeply cleft on the inner margin. Prothorax longer than the head, the hind angles slightly curved. Meso- and meta-thorax smaller, but similar in shape, each thoracic segment bearing four pairs of hairs on the dorsal plate. The abdominal plates one to seven of the same form and bearing a moderate carina near the posterior edge of the segment. Eighth segment a little larger, slightly wider, and also bearing a carina, lateral edges of each abdominal segment bearing three short hairs. The last segment small, posterior angles produced backward, but hind edge of segment truncate; caudal appendages long, blunt, spiny, slightly depressed, and bearing on the upper surface a hump-like protuberance provided with a few spines. The spiracles are nine in number, and are arranged the same as in *C. frigidum;* the color, however, is black. Legs small and spiny, tarsi bearing two claws. The anal proleg is stout and covered with numerous short hairs. The under surface is of a purer white than in *C. frigidum*, but bears similar markings. The latter resemble those of the preceding species in form and arrangement, but are slightly darker in color. The spots composing the first lateral row are more elongated and all the ventral spots are somewhat larger than in the preceding species. The time spent in this stage is about one month, of which about three weeks are passed in feeding. When full grown the larva burrows into the ground to a depth of several inches, and after preparing a cavity throws off its skin and goes into the pupal stage.

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[1] Burgess, A. F. Notes on certain Coleoptera known to attack the gypsy moth. *In* 44th Ann. Rpt. Mass. State Bd. Agr. f. 1896, p. 412-431 (p. 426-428), pl. 3-5, 1896.

LENGTH OF TIME REQUIRED TO COMPLETE LARVAL STAGE.

From several feeding records kept of larvæ that hatched between June 20 and 24, 1909, it was possible to secure information on the length of time required to complete the different larval stages. It was found at that time of year that an average of 3 days was required to pass the first stage, 5 days for the second, and 12 days for the third, or a total of about 20 days between hatching and cessation of feeding. No notes were secured with this series of larvæ as to the time when feeding ceased and pupation began, but observations on larvæ in 1911 showed that 6 days were spent in the prepupal stage.

Some data secured in 1912 show that from 3 to 5 days were required for larvæ to complete the first stage, 4 to 6 days for the second, and 12 to 17 days for the third. A fair average for these would be 4 days for the first stage, 5 for the second, and 15 for the third, or a total of 24 days for the active feeding period. These larvæ hatched May 20 to May 28—much earlier in the season than those referred to under 1909 when the weather was cooler, and this wholly or in part explains the longer time required to complete the growth in 1912.

FOOD CONSUMED BY LARVÆ.

The most natural food of these beetles and their larvæ is cutworms but it was not always convenient to collect these in sufficient numbers for the feeding experiments, so caterpillars of *Porthetria dispar* and *Malacosoma americana* were used. A series of individual records was kept in 1909 and 1910 with caterpillars of these species as a source of food supply. In 1911 a series was kept, feeding pupæ of *M. americana* only, after the cocoons had been removed.

TABLE 24.—*Food eaten by larvæ of Calosoma calidum, 1909–10.*

Date hatched.	Date ceased feeding.	*Malacosoma americana* caterpillars, fifth and sixth stages.	*Porthetria dispar* caterpillars, sixth stage.	Total.	Date hatched.	Date ceased feeding.	*Malacosoma americana* caterpillars, fifth and sixth stages.	*Porthetria dispar* caterpillars, sixth stage.	Total.
1909.					1910.				
June 20	July 8	[1] 10	13	23	May 29	June 22	9	1	10
23	12	4	13	17	June 2	24	10	5	15
23	12	3	16	19	2	22	9	0	9
24	13	1	21	22	7	30	7	4	11
24	16	3	20	23	7	28	7	3	10
24	17	1	13	14	7	28	13	5	18
					7	30	6	8	14

[1] Two of these caterpillars were in the third stage.

The average number of caterpillars eaten by each larva in 1909 was 20, and in 1910, 13. Sixth-stage caterpillars only were supplied in the latter series, while several fifth-stage caterpillars were offered in the former. Twenty large caterpillars (the same or similar to *Porthetria dispar*, or *Malacosoma americana*) is about a fair average for each larva to consume.

The larvæ in Table 24 were active and fed over an average period of 21 days after hatching, and then entered the ground for pupation. Larvæ of *C. scrutator* are active the same number of days but have a somewhat greater capacity for food.

Five larvæ were fed from hatching to maturity in 1911 on pupæ of *M. americana* from which the cocoons had been removed. From 6 to 10 pupæ were devoured by each larva, or an average of 9. Larvæ of this species did not attack and devour as many pupæ as caterpillars, and the same is true of other species of Calosoma. When a Calosoma larva attacks and devours a pupa, it usually feeds until nothing remains but the empty case, but when a caterpillar is attacked part of the fluids and body contents are lost in the struggle of the caterpillar to free itself from the Calosoma.

HABITS OF LARVÆ.

May 29, 1911, an experiment was begun to test the climbing of these larvæ. (Pl. III.) Six newly hatched larvæ were placed inside the tin circle and caterpillars of *Malacosoma americana* were liberated upon the tree and on the ground. Later in the day two of the larvæ were noted feeding upon caterpillars at the base of the tree. May 30 the larvæ were again noted feeding upon caterpillars on the ground, on which date five were found buried in the earth. These first-stage larvæ remained in the circle until about June 4 before transforming to the second stage and were deprived of food some of the time until they were on the verge of starvation. Later on, July 17 and 21, other first-stage larvæ were added and kept under observation for a few days. They were placed upon the tree frequently, but each time fell to the ground almost immediately. Second-stage larvæ were tested but did not climb except on one occasion when one was seen crawling up and down the trunk about a foot from the ground. The others died of starvation and did not attempt to climb so far as could be observed, although they were under observation for several days. One third-stage larva was left in the experiment for a few days and it made no attempt to climb for food but remained on and in the earth.

In all cases starvation resulted unless food was placed on the ground. These facts show conclusively that this species is terrestrial in habit during the larval stages and the same is usually true of the adults.

PUPA.

Pupæ of this species averaged as follows: The females, 17.5 mm. long and 7.7 mm. wide; the males, 15.7 mm. long and 6.8 mm. wide.

Close observations were made upon a series of larvæ fed in jars in 1911 to determine the actual time required to pass the pupal stage. It was found that 1 male pupa matured in 11 days, while the females matured in 9 and 10. An average of 10 days was required for each, including both sexes in the series. The adults from the pupæ in question issued from July 4 to 10.

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Page 128. The species was found in great numbers in a field infested with the vagabond crambus (*Crambus vulgivagellus*), and probably feeds on them.

1882. Schaupp, F. G. Biological notes on, and description of the larva of *Calosoma calidum* Fab. *In* Bul. Brooklyn Ent. Soc., v. 5, p. 33–34.

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Page 141. Classification and brief description.

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Page 28. Reported as feeding upon the gipsy moth.

1895. Comstock, J. H., and Anna B. Manual of the Study of Insects. 701 p., 797 fig. Ithaca.

Page 519. Beetle called the "fiery hunter," known to climb trees in search of food.

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Pages 381, 383. Brief notes on the adults feeding upon *P. dispar* caterpillars.

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Pages 426–430. Contains description of the larvæ in all stages and notes on habits of adults and larvæ.

1898. Burgess, A. F. Notes on predaceous beetles, 1897. *In* 45th Ann. Rpt. Mass. State Bd. Agr. f. 1897, p. 402–411.

Page 409. Notes on rearing the species.

1899. Fletcher, James. Report of the entomologist and botanist. *In* Canada Expt. Farms Rpts. f. 1898, p. 167–219, 24 fig.

Page 190, fig. 14. Notes on the variations of color in the spots of the elytra; also refers to the larva of the "cutworm lion."

1910. Blatchley, W. S. The Coleoptera or Beetles of Indiana. 1386 p., 590 fig.

Brief description with notes on occurrence and habits.

CALOSOMA MORRISONII Horn.

ORIGINAL DESCRIPTION.

Black, moderately shining. Head moderately closely punctate, rugulose at the sides, mandibles transversely wrinkled. Thorax twice as wide as long, base and apex nearly equal, sides strongly arcuate in front, oblique behind, hind angles very obtuse, lateral margin narrow in front, more widely reflexed posteriorly, the basal impressions moderately deep, apex feebly, base more distinctly emarginate, median line distinct, surface moderately closely punctate and more rugulose at the sides and along the base. Elytra oval, widest behind the middle in both sexes, humeri distinct, surface rather shining, with about fifteen rows of rather fine not closely placed punctures, the intervals with a single row of finer and more distinct punctures, the fourth, eighth, twelfth, and submarginal intervals with a series of moderately distant larger golden punctures. Prothorax beneath sparsely punctate, metathorax at sides more coarsely, abdomen sparsely punctate at the sides. Length .72–.82 inch, 18–20 mm.

The male has three joints of the anterior tarsi spongy pubescent beneath. This species from the evident golden elytral spots must be associated with *calidum* and *tepidum*, than either of which it has much smoother elytral sculpture although resembling them in general form. It might be mistaken for a smooth variety of *obsoletum*, but the elytra are more dilated, their sculpture smoother, and without the imbricated appearance. The base of the thorax is distinctly bisinuate in *obsoletum* and simply emarginate in the present species as well as in those with which it is associated.

Collected by Mr. H. K. Morrison in Colorado. With it I associate his name as an evidence of my appreciation of his industry and success in adding to a knowledge of our fauna.

EARLY RECORDS AND DISTRIBUTION OF THE SPECIES.

This species was described by Horn in 1885[1] from specimens that were collected in Colorado by H. K. Morrison. Specimens that are deposited in a few museum collections in the United States bear locality labels from Colorado and southern California. It appears not to be particularly common in any State, although the most have been reported from Colorado.

CALOSOMA TEPIDUM Lec.

(Syn.: *C. irregulare* Walk.)

ORIGINAL DESCRIPTION.

Black, with head and thorax closely wrinkled, thorax very broad, narrowed at the posterior end, sides much rounded, margin somewhat reflexed, with base lightly bisinuate, marked on both sides, elytra extended slightly posteriorly, finely striate, with spaces between the striæ much corrugated, almost broken into granules, and with bronze-colored pits in triple row.

Length .75.

Shorter than *C. calidum* and differs in having elytra quite rough; it seems similar to *Callisthenes*, and shows its likeness in antennæ, 5th and 6th joints, glabrous margins, pubescent at the base, with the glabrous part poorly defined, and 7th to 11th joints equally pubescent, described in this species.

Oregon. I have seen another specimen in the Collection of the Exploring Expedition.

This species was described by Le Conte in 1851. Mr. J. K. Lord published in 1866 the description of a new species, *Calosoma irregulare*, described by Walker, the habitat of which was not given and compared it with *C. calidum*, *C. frigidum*, and the Siberian *C. denticolle*. In 1871 Horn reduced this species to a synonym of *C. tepidum*. There are no records at hand to show that *C. irregulare* is represented in any of the public museums and experiment-station collections of the United States, consequently the writers have not been able to study specimens.

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[1] Horn, G. H. Contributions to the Coleopterology of the United States. *In* Trans. Amer. Ent. Soc., v. 12, p. 128–162, pl. 4–5, 1885.

C. tepidum has been reported from the following States: Arizona, California, Colorado, "Dakota," Idaho, Montana, Nebraska, Nevada, Oregon, Utah, Washington, and Wyoming. British Columbia, Alberta, and Vancouver Island are points in Canada from which specimens have been collected.

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1852. LeConte, J. L. Description of new species of Coleoptera from California. *In* Ann. Lyc. Nat. Hist. N. Y. f. 1851, v. 5, p. 125–216.

Page 199. Original description of *C. tepidum* in comparison to *Calosoma calidum*. Habitat, Oregon.

1866. Lord, J. K. The Naturalist in Vancouver Island and British Columbia, v. 2, 375 p.

Page 312. Description of *Calosoma irregulare* by Walker without locality for type specimen. Comparisons are made of this species with *calidum* and *frigidum* and mention made of its alliance to the Siberian *C. denticolle*.

1870–1871. Horn, G. H. Contributions to the Coleopterology of the United States. *In* Trans. Amer. Ent. Soc., v. 3, p. 69–142, pl. 1.

Comparisons of specimens collected in Oregon and California, also the following notes under *C. tepidum:* "This species has been redescribed as *C. irregulare* by Walker, Naturalist in British Columbia, Lord, Vol. II, p. 312."

1890. Harrington, W. H. On the list of Coleoptera published by the Geological Survey of Canada, 1842–1888. *In* Canad. Ent., v. 22, no. 7, p. 135–140.

Page 139. Catalogue of the Coleoptera determined for the Geological Survey of Canada by Dr. J. L. LeConte notes the collection of *C. tepidum* in British Columbia.

CALOSOMA AUROPUNCTATUM (Payk.).

ORIGINAL DESCRIPTION.

[Translation.]

Black, smooth, with thorax emarginate posteriorly, elytra finely punctate-striate, and punctures of uneven depth a little larger in triple row.

Description of male.

Head entirely black; antennæ becoming brown at the apex.

Thorax black, smooth, marginate, obovate, almost twice broader than long, sides rounded; truncate anteriorly, somewhat emarginate posteriorly.

Elytra black, scarcely broader than the thorax, very finely punctate-striate: punctures a little larger depressed in triple row.

Sternum black.

Abdomen black.

Feet black. Tibiæ curved.

In size and length it almost exceeds the preceding, (*Carabus reticulatus*) but it does not equal it in breadth.

Female similar to male, but somewhat greenish above in color, coppery punctures in triple row, abdomen scarcely broader, and anterior tibiæ shorter. Habitat rare in southern Switzerland. It differs from *Carabus inquisitor* in color, in emarginate thorax and smoother elytra, from *Car. reticulatus* in color, body more elongated and elytra not at all reticulated.

Synon. Herbst. *Carabus auropunctatus.*, Fab. Mant. Ins. p. 197. No. 35, *Car. indagator*? is related to this, but this one is wingless as only a hasty description was seen by the author.

EARLY RECORDS OF THE SPECIES.

This species was first described by Paykull in 1790 and its habitat given as southern Switzerland. Dejean, in 1826, put it in the genus Calosoma as it had previously been identified as Carabus. Gebler, in 1833, writes of the great similarity of this species to *C. denticolle* Gebl. Houlbert and Monnot, in 1905, made a study of *C. auropunctatum* and came to the conclusion that *C. sericeum* of Fabricius and *C. indagator* of Gyllenhal were synonyms of it.

IMPORTATIONS.

The only importation of this species was received at the gipsy moth parasite laboratory June 1, 1909, from Miss Ruhl. The shipment contained nine males and nine females alive and three males and one female dead. Requests were made for Miss Ruhl to collect more and forward them but it seemed impossible for her corps of collectors to find them owing to the scarcity of the species in central and southern Europe.

HABITS OF ADULTS.

June 29, 1911, one female was tested to ascertain if adults of this species naturally climb trees in search of prey. (Pl. III.) The beetle when left inside the circle crawled about and up to the base of the tree but did not attempt to climb. When put upon the bark, head upward, it would turn around very quickly and climb downward to the ground. When placed upon the tree near the top, the beetle would lose its footing and fall. No climbing experiments were conducted with the larvæ.

This species is evidently terrestrial in habit.

FOOD CONSUMED BY ADULTS.

Feeding records were kept daily of a series of pairs of beetles received from Europe June 1, 1909, and these records were extended over two years, 1909 and 1910, as shown in Table 25.

TABLE 25.—*Feeding records of four pairs of Calosoma auropunctatum, 1909–1910.*

1909.

Pair No.	Feeding record started.	Ceased feeding.	Sixth-stage caterpillars.		Total.
			Malacosoma americana.	*Porthetria dispar.*	
2709	June 2	July 16	81	47	128
2710	2	19	85	48	133
2711	2	Aug. 16	95	67	162
2712	3	9	115	80	195
Average per pair					155

1910.

Pair No.	Female emerged and record started.	Ceased feeding	*Malacosoma americana,* fifth and sixth stages.	*Porthetria dispar,* sixth stage.	*Estigmene acraea,* sixth stage.	Total.
2709	May 26	Aug. 12	65	166	11	242
2710	23	12	84	[1] 156	11	253
2711	June 7	5	57	[2] 140	1	199
2712	May 24	July 30	53	125	3	181
Average per pair						219

[1] Besides two pupæ.

[2] Besides one pupa.

The male of pair No. 2712 died June 5, 1910, and the female alone consumed 151 of the 181 caterpillars totaled for that pair. Male No. 2709 died June 10 but another female was added to that jar, making two females. The males in the other two jars, together with all the females, lived to the end of the feeding season.

The average number of caterpillars consumed per pair in 1909 was much less than in 1910, which was probably partly due to the record being started a little late and because they were mostly first and second year beetles at that time. Female No. 2711 deposited 19 fertile eggs during the latter part of June, 1910, and more food was consumed in that year than in 1909. None of the other females in Table 25 reproduced during either year. The average number of caterpillars consumed per pair in 1910 is about the same as the average for *C. calidum*, which was 226.

REPRODUCTION.

Out of the lot of beetles imported in 1909 only three eggs from which larvæ hatched were deposited that year. Most of the beetles entered hibernation and lived to emerge during the spring of 1910, and during that year 152 fertile eggs were secured from the six females.

No copulation was observed among these beetles, but deposition of eggs was recorded almost continuously between May 26 and July 27. Only one female lived to issue in the spring of 1911 and there were no males left for mating.

LONGEVITY.

One female of the lot of beetles received from Europe June 1, 1909, lived until August 17, 1911. This female did not deposit eggs in any of the three years of her existence at the laboratory. It was a pupa in the late summer of 1908 or earlier and passed two winters and three summers at Melrose Highlands, Mass. Three females of the same lot died in hibernation during the winter of 1910–11. Notes secured on the length of life of this species show that the limit is three years or longer.

HIBERNATION.

The beetles received in 1909 fed freely for a time and entered hibernation between July 16 and August 20, the average date being July 31.

They emerged in outdoor cages in the spring of 1910 between May 3 and June 14, the average date being May 23. The cavities where they spent the winter were from ½ to 4 inches deep, or an average of 3½ inches.

A few of these old beetles again entered hibernation in the fall of 1910 with some young adults reared the same year, the average date of entrance being August 9. Only three females (one old and two young) were still alive in the spring of 1911, and these were unearthed June 7 and June 23. The beetles hibernated from 2 to 12 inches below the surface.

THE EGG.

The egg is white, slightly approaching a creamy shade.

Twelve eggs were measured in 1910 soon after deposition, giving an average length of 4.5 mm. and a width of 2.2 mm. The adults of *C. auropunctatum* Payk. run slightly larger than *C. calidum* Fab., but the eggs are much smaller. The eggs of the former species are elliptical in form and taper gradually toward one end.

The average number of days passed in the egg stage was 9, for 111 eggs observed in 1910. Fifteen days were required for hatching eggs deposited the latter part of May, when the weather was cool, but only three to six days were necessary late in June or early in July.

DESCRIPTION OF LARVA.

First stage.—Medium to small size, fusiform. Average length of 12 specimens, 9 mm.; width, 2.2 mm. Caudal appendages long, straight, bearing a few long spines. Color shining black above, ventral plates grayish-brown.

Second stage.—Somewhat stouter than first stage. Average length of nine specimens, 16.5 mm.; width, 3.5 mm. Caudal appendages stout at base, rather erect to dorsal protuberance, curved slightly upward and gradually tapering beyond protuberance. Protuberance short, erect, and located less than one-half the distance from base to tip. Color same as in first stage above, ventral plates dark brown.

Third stage.—Rather robust in form. Average length of four specimens, 22 mm.; width, 4.9 mm. Caudal appendages short, stout, and rather erect to dorsal protuberance, curved upward beyond this, acute at end. Protuberance more prominent than in second stage. Color of dorsum shining black with metallic luster, ventral plates dark brown. No reddish-brown patch at base of caudal appendages in second or third stages.

TIME REQUIRED TO COMPLETE LARVAL STAGES.

From 3 to 7 days are required for the first stage, or an average of 5; 3 to 5, or an average of 4, for the second; and 10 to 14, or an average of 11, for the third. The larvæ are active and feed about 19 or 20 days. Four days are passed in the prepupal stage.

TABLE 26.—*Food required to mature larvæ of Calosoma auropunctatum, 1910.*

No.	Date hatched.	*Malacosoma americana* eaten, sixth stage.	*Porthetria dispar* eaten, fourth to sixth stages.	Total.
2789-A	June 11	5	16	21
2789-B	[1] 11	5	40	45
2789-C	13	3	13	16
2789-H	14	6	46	52
2789-I	13	4	51	55
2789-J.	[1] 16	1	55	56

[1] Larvæ died when full grown.

The average number of large caterpillars required to complete the growth of 12 larvæ, 6 of which are given in Table 26, was 40. The larvæ of this species appear to be very voracious feeders, as from 16 to 56 large caterpillars were destroyed. The average for this species was twice that consumed by larvæ of *Calosoma calidum*.

Two larvæ of this lot pupated and issued as females in July, 1910. They came on the surface of the earth and ate 19 and 27 large caterpillars, respectively, before entering hibernation. These are the only adults that have been reared and indicates that this habit may be constant. This species resembles *C. calidum* in this respect.

PUPA.

Length of female, 19 mm.; width, 7.5 mm. Male, 18.7 mm. long, 7.2 mm. wide.

The larvæ under observation in 1910 ceased feeding June 27 to July 3, then entered the earth and constructed cavities. Pupation took place in 4 days and 12 to 13 days were passed in the pupal stage. The adults in a few days emerged from their cavities and came on the surface in search of food.

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1790. Paykull, G. von. Monographia Caraborum Sveciae. 138 p.

Page 68, no. 41. Original description as *Carabus auropunctatus*.

1798. Paykull, G. von. Fauna Svecica, t. 1, 234 p.

Pages 129–130. Practically the same description as above, with note as to habitat in Southern Switzerland.

1826. DeJean, le Comte. Species Général des Coléoptères, t. 2, 501 p.

Page 203. Description of the species under the name of *Calosoma auropunctatum* and in comparison to *C. inquisitor*. The author gives it as a variety of *Calosoma sericeum* which he had previously thought to be a distinct species. *C. auropunctatum* is recorded as found in Austria, Germany, and France, but everywhere rare.

1830. Gebler, F. A. von. Bemerkungen über die Insekten Sibiriens, vorzuglich des Altai. Ledebours Reise, t. 2, p. 57.

1833. Gebler, F. A. von. Bulletin de la Société Imperiale des Naturalistes de Moscou, t. 6, p. 274.

The species is described as approximately like that of *Calosoma denticolle* Geb. from Siberia.

1877. Marseul, D. A. de. Mélanges. *In* L'Abeille, t. 15 (ser. 3, t. 3), ser. 2, no. 6, 1875, p. 22–24.

Record of a specimen pierced with a pin so as not to wound the ganglia and the beetle lived 18 months with the pin still in the body and fed voraciously during the time.

1887. Mayet, V. Description des larves des *Calosoma Maderae* F. et *Olivieri* Dej. *In* Ann. Soc. Ent. France, ser. 6, t. 7, p. clxxi–clxxiv.

The author states that *C. auropunctatus* is not found in Algeria.

1905–1907. Houlbert, E., et Monnot, E. Coléoptères. Carabides. *In* Trav. Sci. Univ. Rennes, Fauna Ent. Americaine, t. 1, pt. 2, p. 289–379, fig. 68–145.

Page 293. These authors claim that *C. sericeum* Fab. and *C. indagator* Gyll. are synonymous with *C. auropunctatum* Payk.

CALOSOMA CANCELLATUM Esch.

[Pl. XVII, *C.*]

(Syn.: *Calosoma aenescens* Lec.)

ORIGINAL DESCRIPTION.

[Translation.]

Thorax very short, rough, bronze, posterior angles produced, elytra greenish-bronze, obsoletely striate. Crossed with irregular short wrinkles with three series of elevated oblong punctures, tibiæ straight.

From California near San Francisco.

Length 9 lines. Head and prothorax colored very green, thickly punctate; prothorax very short, twice as broad as long, broader anteriorly than posteriorly; indented in front in the middle, straight posteriorly; the broad, blunt hind corners project out prominently, lateral margins broadly turned up, shield black. Elytra not much broader than prothorax, long, indistinctly striate, all the spaces between are uneven because of cross lines; broad intermediate spaces have larger grooves, whereby three rows of long chainlike granules are formed. On elytra all depressions colored light metallic green, all elevations very green. Ventral side of body has on the sides of prothorax and breast green glimmerings; all the rest as well as the legs are black. Middle tibiæ of female straight.

This species was described by Dr. Friedrich Eschscholtz in 1829, who recorded its habitat as California near San Francisco. It has later been taken in Arizona, California, Idaho, Indian Territory, Montana, Nevada, Oregon, Utah, and Washington. Dr. LeConte in 1854 described a new species (*Calosoma aenescens*) as occurring at Fort Vancouver. The writers have had the opportunity of studying the type which is deposited in the Museum of Comparative Zoology, Cambridge, Mass., and find it does not differ from *C. cancellatum* Esch., and it is, therefore, considered as a synonym of that species.

COLLECTIONS AND SHIPMENTS.

The late H. M. Russell, of this bureau, on June 9, 1910, forwarded a female of *C. cancellatum* Esch. from Compton, Cal., accompanied by a letter stating that he had found "the larva of the beetle feeding in a sugar-beet field on larvæ of *Peridroma saucia.* It disappeared about May 15 and was found as a beetle 3 inches below the surface of the ground June 6, 1910." This beetle died June 14 after its arrival at Melrose Highlands, Mass.

April 5 and 6, 1914, Mr. J. E. Graf, also of this bureau, collected at Compton, Cal., six males and two females of this species and forwarded same alive to Melrose Highlands, Mass. They were collected on low shrubbery, and Mr. Graf stated that they feed on coleopterous and lepidopterous larvæ.

FOOD OF ADULTS.

The adults received at Melrose Highlands, Mass., April 16, 1914, were offered larvæ of *N. clandestina,* of which one pair of beetles destroyed from 5 to 12 large larvæ per day. *M. americana* and *P. dispar* larvæ were consumed after May 15 to about July 8, when some of the adults died and others remained inactive in the earth.

REPRODUCTION AND HIBERNATION.

April 16, 1914, one pair of adults from California were enclosed in a rearing jar and fed regularly at intervals. From May 8 to June 18 eggs were noted in the earth, and a total of 11 larvæ hatched from eggs deposited by this female. In another jar containing five males and one female from the same source as above were found seven larvæ during the season. From these records it would appear that this species is not a prolific breeder.

No adults of this species lived to enter hibernation in the fall.

EGG.

Six eggs that had been preserved in alcohol averaged 3.7 mm. in length and 1.5 mm. in width. Color creamy-white, form elliptical, very slightly larger near the anterior end, tapering slightly toward the posterior.

The eggs were not found as soon as deposited, therefore close data on time required to pass the egg stage were not secured. It probably ranges from 6 to 12 days under Massachusetts conditions when the eggs are deposited in May, possibly less in California, the native habitat.

BRIEF DESCRIPTION OF LARVA.

First stage.—Small, rather slender larva. Average length of six newly hatched specimens that had been preserved in alcohol 8.1 mm., width 2.1 mm. Color dull black dorsally, ventral plates dark brown. Ventral and lateral plates lightly clothed with short brown hairs. Caudal appendages (1.4 mm. long) very slender.

Second stage.—Form similar to first stage. Average length of six specimens 17.7 mm., width 4.2 mm. Caudal appendages straight and rather blunt at apex. Color similar to first stage, but of somewhat lighter shade in the specimen studied.

Third stage (Pl. XVII, *G*).—Rather long, slender larva. Average length of six alcoholic specimens 25.5 mm., width 5.2 mm. Caudal appendages rather short (1.4 mm.), stout, slightly curved in center. Each appendage bearing stout dorsal protuberance on the middle. Appendages taper to a long point beyond dorsal protuberance. Color dull to shining black above, brown below. Ventral plates rather thickly set with hairs and regular in outline. Anterior ventral plates of abdominal segments 2 to 7 oval in form without regular marginal notches. Posterior median plates rectangular in form and outer ventral plates on third to seventh abdominal segments oval. Posterior angles of anal segment broad at base, acute at tip, projecting slightly upward.

LARVAL RECORDS.

Many larvæ were reared in individual jars during 1914 which were fed mostly on *N. clandestina* and *M. americana* larvæ. Those reared hatched May 8, 11, 22, and 24 and ceased feeding between June 9 and 15. The larvæ that hatched late in May matured in much shorter time—18 to 22 days, while those that hatched early in May required about one month. One and sometimes two large caterpillars were consumed by one beetle larva each day excepting during the molting periods, or a total of from 20 to 35 before maturity. Proportionately more would be destroyed if small caterpillars were offered.

Time spent in the larval stages for a few specimens averaged as follows: For first, 5 days; for second, 6 days, and for the third about 9 to 12 days to the date larvæ cease feeding for making cavity. About 4 days additional is passed in the cavity before pupation.

HABITS OF THE LARVÆ.

A first-stage larva put on the bark of a white oak post, after several tumbles reached the top (6 feet). Each time placed on with head upward, it would turn the opposite direction and descend, several times circling the post. Third-stage larvæ showed about the same inclination to reach the ground when placed upon the post. They were not able to ascend more than three feet before falling.

The slowness and awkwardness with which these larvæ handle themselves on trees indicated that their natural habits are similar to those of *C. calidum* Fab., that is, remaining always on or near the ground in search of food.

PUPA.

Two pupæ (1 male and 1 female) were preserved in alcohol from the rearings of 1914, the average measurements of which were 18.2 mm. in length and 7.3 mm. in width. June 20, 1 pupa was unearthed from a cavity at the bottom of a jar which was then about 5 days old, as determined from the colorations of the tarsi, eyes, and buccal parts. The color of the pupa as a whole grew darker daily until it died June 25. It is probable that about 10 to 12 days are required to pass the pupal stage for this species.

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1829. Eschscholtz, J. F., Zoologischer Atlas enhaltend Abbildungen neuer Thierarten wahrend Kotzehue's, etc. Part I, Taf. XXV, p. 23.

Original description of *Calosoma cancellatum.*

1854. LeConte, J. L., Descriptions of some new Coleoptera from Oregon, collected by Dr. J. G. Cooper, of the North Pacific R. R. Expedition. Proc. Acad. Nat. Sci. Phila., T. 7, p. 16.

Description of *C. aenescens* from Fort Vancouver; comparison is made with *Calosoma tepidum* and *calidum.*

1857. LeConte, J. L., Report upon Insects Collected on the Survey (Coleoptera), p. 30.

Redescription of *Calosoma cancellatum* with a citing of the original description by Eschscholtz. Also a note that *C. aenescens* was collected in Sacramento, California.

CALOSOMA SUBAENEUM Chaud.

ORIGINAL DESCRIPTION.

[Translation.]

Length 17 mm. Like *discors* in form, but more narrow and much smoother. Head very slightly punctate, base and anterior margin smoother, impressions of face heavier. Thorax a little smaller, very finely and irregularly wrinkled above, more punctured toward sides and the base and especially towards the posterior angles which are less prolonged backward, more broadly rounded, sides of base very hollow near the angles, lateral margin reflexed, especially backward. Base of elytra almost as broad as thorax, broadening toward the middle and rounding somewhat to the end, one half longer than broad, humeral angles more square although rounded; anterior part of sides rectilinear, less convex above; striæ not impressed, composed of rows of small dots, moderately near each other, from each of which a very small transverse wrinkle covers the interstices; these dots and transverse wrinkles are more prominent at the sides and near the end and give the outer border a very wrinkled appearance. Shining black the upper side slightly tarnished; sides and base of thorax as well as all surface of the elytra, olive green bronze; on each are three rows of dots, slightly larger than those on the striæ, the first two are obsolete near the base. As it differs from all other species on account of the sculpture of the elytra and also by its narrowed form I have placed it provisionally at the end of the series.

One specimen reported from California by M. Lorquin.

This species was described as above by Baron De Chaudoir in 1869.[1] It occurs in California, Idaho, and Washington.

CALOSOMA MONILIATUM Lec.

(Syn.: *C. laqueatum* Lec.)

ORIGINAL DESCRIPTION.

Obscurely bronze, dark, head and thorax closely rugose and punctate, the thorax twice shorter than broad, somewhat narrowed posteriorly, sides moderately rounded, margin scarcely reflexed, base broadly emarginate, angles slightly produced, elytra one-half longer than broad, closely grooved, calli on both sides smooth, oblong, and pits arranged in triple row. Length .65. Oregon. Length 17 mm. Oregon. Montana.

Longer than rest, about the size of *Carabus serratus* Say.

This species was described by LeConte in 1852.[2]

In 1860 LeConte[3] described *Calosoma laqueatum* (Proc. Phila. Acad. Nat. Sci., vol. 12, p. 318), but later reduced it to a synonym of *moniliatum*. *C. moniliatum* occurs in Arizona, California, Idaho, Montana, Nebraska, Oregon, Washington, and in the Northwest Territory, Canada.

CALOSOMA CHINENSE Kirby.

[Pl. VII, fig. 10.]

ORIGINAL DESCRIPTION.

Dusky, blackish-coppery above, rough, elytra marked with golden punctures in triple row.

Length of body, 15 lines.

Habitat in China.

Body black underneath, blackish-coppery above, dark. Head marked with most minute confluent punctures. Thorax rough with close punctures or minute wrinkles, indistinctly canaled or furrowed dorsally, and deeply marked posteriorly on both sides. Elytra oblong-quadrate, roughened with very numerous, very minute granules, marked above with golden punctures in triple row. Epipleura very narrow.

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[1] Chaudoir. Descriptions de Cincindélètes et de Carabiques nouveaux. *In* Rev. et Mag. Zool. (ed. by Guéren-Méneville), ser. 2, t. 21, p. 22-28.

[2] LeConte, J. L. Description of new species of Coleoptera from California. *In* Ann. Lyc. Nat Hist. N. Y. f. 1851, v. 5, p. 125-216 (p. 200), 1852.

[3] LeConte, J. L. Notes on Coleoptera found at Fort Simpson, Mackenzie River, with remarks on Northern species. *In* Proc. Acad. Nat. Sci. Phila., v. 12, p. 315-321 (p. 318), 1860.

EARLY RECORDS OF THE SPECIES.

The original description of this species was published by Kirby in 1818,[1] its habitat being given as China. In 1831 Dejean[2] redescribed it as coming from the same country. The latter author compared it with *auropunctatum* Payk. in general markings and says it should be placed near *senegalense* Dej. The literature concerning this species is rather limited. The writers were able to secure only the two references above cited.

OCCURRENCE AND IMPORTATIONS.

Three hundred and fifty-three adults were collected and shipped to the gipsy moth parasite laboratory in two years. Along with the second shipment in 1910 were received specimens of *Carabus procerulus* Chaud., *C. tuberculatus* Fisch., and *Damaster blaptoides* Kollar. A specimen received January 5, 1910, was collected and mailed by Rev. H. Loomis, 53 Main Street, Yokohama, Japan, while the two large shipments were made from the Imperial Agricultural Experiment Station, Tokyo, by Prof. S. I. Kuwana. The beetles were packed singly in wooden boxes with damp sphagnum moss. About 40 of these small boxes were inclosed in a large wooden box. Arrangements were made with the steamship company whereby the boxes were kept in cold storage as far as Vancouver, British Columbia, and were then shipped by express, in larger boxes containing ice. The moss in many of the small boxes was still damp on arrival, and the beetles on the whole were in very fine condition, 83 per cent being alive on receipt. They were en route 18 days.

HABITS OF ADULTS.

The adults of this species are able to fly to some extent. They also climb trees, which was demonstrated in 1911. Experiments conducted indicate that the adults are able to attack either ground or tree inhabiting caterpillars.

FOOD CONSUMED BY ADULTS.

Daily feeding records were kept of four pairs of beetles received from Japan, July 22, 1910.

TABLE 27.—*Feeding records of four pairs of Calosoma chinense, 1910.*

Pair No.	Date received from Japan.	Ceased feeding.	Male died.	Female died.	Fourth to sixth stage caterpillars consumed.		
					Porthetria dispar.	*Estigmene acraea.*	Total.
4524	July 22	Sept. 8	Aug. 24	Sept. 9	55	138	193
4525	22	9	....	....	61	132	193
[3] 4526	22	9	....	....	50	92	142
4527	22	9	[4] July 30	....	33	125	158

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[1] Kirby, W. A century of insects. *In* Trans. Linn. Soc. London, v. 12, p. 375-482 (p. 379, no. 5), pl. 21-23, 1818.

[2] Dejean, le Comte. Species Général des Coléoptères, t. 5, 883 p. (p. 563). Paris, 1831.

[3] Female deposited eggs.

[4] Male added from same shipment to replace dead male.

All the caterpillars of *Porthetria dispar* eaten by the beetles were in the sixth stage, while the larvæ of *Estigmene acraea* ranged from the fourth to the sixth stage. An average of 172 large caterpillars were eaten by each pair from the late date the beetles were received to the end of the feeding season. The only pair of beetles that lived emerged from hibernation June 7, 1911, and immediately began to feed actively. From this date to July 22 the pair ate 63 sixth-stage caterpillars of *Malacosoma americana* and 57 fifth and sixth stage caterpillars of *P. dispar*, a total of 120. This number added to 172, the average number eaten by 4 pairs from July 22 to the end of the previous feeding season, equals 292, or approximately the number eaten by the Calosoma of equal size.

REPRODUCTION.

July 22, 1910, four pairs were placed in battery jars for rearing and feeding records. One pair was observed in copulation August 3 and from August 3 to 8, and later 54 eggs were deposited.

July 28, 1911, eight pairs of beetles just received were placed in large battery jars, as also one pair reared in 1910 from eggs deposited that year. The male of the latter pair died July 8, but another was added and the pair entered hibernation August 8 without having reproduced. Two females of the foregoing 8 pairs reproduced in 1911; one deposited 11 eggs and another 112 between August 7 and 17.

One of the eight pairs that entered hibernation in the fall without reproducing emerged May 13, 1912, and the female laid 217 fertile eggs from May 25 to July 1, and died July 10. This is the largest number of eggs deposited by a single female of this species in confinement.

The notes secured indicate that the species is fairly prolific under favorable conditions and, if it can be established, will undoubtedly prove very beneficial.

LONGEVITY OF ADULTS.

One female reared from the egg in 1910 was active during the season of 1911 and entered hibernation that fall. June 20, 1912, the cage was dug up but the female was dead in the earth, 3 inches below the surface. She died some time during the hibernation period and lived practically one year after issuance as an adult.

Many adults were received from Japan during the summer of 1911 and several of them successfully hibernated the following winter, and upon emergence were planted in colonies. The few that were left at the laboratory for rearing during the season of 1912 died toward the end of the summer before reentering hibernation. These adults lived two summers and one winter in confinement.

The data at hand show that the adults live at least two years, and it is very probable that three years is the usual limit as with some of the other species of the genus.

HIBERNATION OF ADULTS.

Three pairs of beetles received from Japan July 22, 1910, fed until September 10 of the same year and entered hibernation. As it happened, the beetles were collected and shipped at the time of their greatest activity, and as they were deprived of food en route for about three weeks, this probably had some influence on the date on which they entered hibernation. These beetles made cavities from 4 to 6 inches deep in loose soil, but all died before emerging the following spring.

One pair of adults reared in 1910 issued from pupæ September 13 and 18 and on September 26 were transferred to hibernation cages out of doors. June 7, 1911, the male emerged and the female was removed on that date. Both were in cavities 3 inches below the surface. The male died during the summer of 1911, but the female again entered hibernation August 12.

July 8, 1911, a large shipment of adults was received from Japan. Sixty-three males and 48 females out of the shipment were placed in a large outdoor hibernation cage and food was furnished them until they sought hibernation. Slightly less than one-third of these emerged successfully the following spring. In Massachusetts August 12 is the average date for entering and June 7 for emerging from hibernation.

There can now be no question that adults of this species can withstand New England winters.

COLONIES OF CALOSOMA CHINENSE LIBERATED IN 1911 AND 1912.

August 2, 1911, 60 females and 50 males, received from Japan July 28, were liberated in marsh land covered with weeds and grass along the Charles River in Cambridge, Mass. Larvæ of *Estigmene acraea* were so abundant in this area that 2,500 specimens had been collected for use at the laboratory just previous to the date (Aug. 2) on which the beetles were liberated. On August 4 Mr. W. L. Whithead visited the colony and saw four beetles, 2 of which were feeding upon caterpillars. This colony was visited by Mr. Dudley on May 7, 1912, and again on June 4. No insect life of any kind was found on the marsh on the former visit; on the latter date one male of *Calosoma chinese* was found a few feet from where the colony was originally planted. At the time of this visit there was no evidence of the feeding of caterpillars of *Estigmene acraea* on the weeds and grasses, and it is probable that the beetles were forced to migrate in search of food. No beetles have since been found in this colony.

At Stoneham, Mass., May 15, 1912, 15 males and 15 females, which were received from Japan in July, 1911, and which hibernated in a large outdoor cage in the laboratory yard during the following winter, were liberated in a market garden where cutworms were doing considerable damage. On June 4 the colony was visited by Mr. Dudley but no adults or larvæ were found. The cutworms at this time were not so numerous, but caterpillars of *Pontia rapae* and *Autographa brassicae* were present on the cabbage plants. No further evidence has been found that the species has become established.

Pelham, N. H., June 21, 1912, Mr. H. I. Winchester took 128 first, second, and third stage larvæ from the laboratory and liberated them in a woodlot badly infested with the gipsy moth. An examination was made in the fall of 1913 but no traces of the beetles were secured.

THE EGG.

Egg white, approaching a creamy shade, almost elliptical in form, slightly curved, usually a little larger at one end. Ten fresh eggs averaged 4.4 mm. in length and 2 mm. in width.

BRIEF DESCRIPTION OF LARVA.

First stage.—Small, rather stout. Average length of 10 specimens, 7.8 mm.; width, 2 mm. Caudal appendages 2.4 mm. long, straight, slender, bearing many long slender spines. Color blackish bronze above, ventral plates dark brown.

Second stage.—Stout. Average length of 10 specimens, 14.4 mm.; width, 3.3 mm. Caudal appendages long, rather erect, and curved upward beyond dorsal protuberance which arises less than one-half the distance between base and tip. Color slightly lighter than in first stage.

Third stage.—Robust in form. Average length of 10 specimens, 22.5 mm.; width, 4.3 mm. Caudal appendages similar to those in second stage, dorsal protuberance prominent, acute. Color bronze to blackish bronze, with pronounced metallic luster. No reddish-brown patch on dorsum of last segment in second and third stages.

LENGTH OF TIME REQUIRED TO COMPLETE THE LARVAL STAGES.

Observations were made on larvæ in 1911 to determine the length of time required to complete each stage. The records indicate that the first stage requires 4 days, the second 8, and the third 14; about 7 days additional are required in making cavities for pupation.

TABLE 28.—*Food eaten by larvæ of Calosoma chinense.*

No.	Date hatched.	Number *Estigmene acraea* caterpillars eaten, fourth to sixth stages.	Number *Hyphantria cunea* caterpillars eaten, fourth to sixth stages.	Number *Porthetria dispar* pupæ eaten.	Total.
	1910.				
4526–AC	Aug. 15	5	54	3	62
4526–AE	...do....	4	38	1	43
4526–AF	...do....	4	51	2	57
4526–AH	...do....	2	49	2	53
4526–AI	...do....	4	63	1	68
4526–AJ	...do....	4	37	3	44
4526–AK	...do....	4	53	1	58
4526–AL	...do....	4	45	2	51
4526–AM	...do....	4	67	2	73

All the larvæ cited in Table 28 died on becoming full-grown, except No. 4526–AK and No. 4526–AM, one of which escaped from the jar whereas the other pupated. The principal reason for the death of the larvæ was that the walls of their cavities for pupation collapsed.

The average number of caterpillars and pupæ required by each larva for food was 57. One caterpillar of *Estigmene acræa* or one pupa of *Porthetria dispar* is equal in sustenance to two or three caterpillars of *Hyphantria cunea*, and on that basis the average amount of food would be 25 to 30 medium-sized caterpillars. This number conforms very closely to the number consumed in 1911 when caterpillars of medium size were used.

HABITS OF LARVÆ.

Some experiments were conducted to ascertain whether these larvæ will climb trees to obtain food. (Pl. III.)

The experiment was started August 15, 1911, with two first-stage larvæ. They remained in the experiment two days, but did not attempt to climb. One larva was placed on the tree and climbed upward about 6 inches before falling.

August 18, 22 second-stage larvæ were left inside the tin circle. One larva was placed upon the bark and climbed slowly, then rested for a time in a crevice, later resuming its journey upward, and finally succeeded in reaching the cage at the top of the tree. This larva also climbed out 6 inches on a small twig. During the night of August 21 one of the larvæ climbed to the food cage on top of the tree, ate part of a gipsy-moth pupa, and descended to the base before 8 a. m., August 22. In this particular case it was impossible to determine whether a second or third stage larva had entered, as one specimen had transformed to the latter stage.

From August 22 to September 4, third-stage larvæ were placed in the circle about the tree. On the afternoon of August 24 one third-stage larva was found feeding in the food cage at the top. On August 30 two different third-stage larvæ were liberated in the circle and later one of these was placed upon the tree, on which it continued to climb at intervals until it reached the food cage. On September 1 one third-stage larva was found in the food cage. It had eaten one pupa of *Plusia brassicæ* and one caterpillar of *Hyphantria cunea.*

The larvæ of this species climb to some extent in all stages. The experiments indicate that the large larvæ climb the best.

PUPA.

The average length of the female pupa is 19.6 mm. and the width 8.1 mm.; the male pupa averages 17.5 mm. in length and 8 mm. in width.

Based on data secured from four specimens, an average of 13.5 days was passed in this stage.

CALOSOMA DISCORS Lec.

ORIGINAL DESCRIPTION.

Wingless, less elongate, black, thorax short, quite intricately rugose, with sides quite rounded, margin somewhat depressed, base emarginate, broader than long at middle, elytra oval, slightly broader than the thorax, densely substriate with striæ and interstices bearing a row of punctures, and with three rows of impressed indistinct dots.

Length 0.75 to 0.82. [Pl. I, fig. 9.]

LeConte [1] adds the following to this description:

San Fran. Mr. Child; Sacramento, Mr. J. Wittick. This species by its short, robust form, and by the absence of wings, simulates Callisthenes, but the antennæ are as in other species of Cal.

Body black, without metallic lustre. Head elongated, rough, with confluent wrinkles and punctures; antennæ with the third joint strongly compressed twice as long as the fourth, fifth and following joints entirely pubescent. Thorax more than twice as wide as the head, and fully twice as wide as its length, not convex, margined, with the sides somewhat depressed behind, but not reflexed; base transversely impressed, and faintly bifoveate; middle part truncate, posterior angles moderately produced, hardly acute at apex. Elytra oval, moderately convex, a little wider than the thorax, marked with faint approximate striæ, which are strongly punctured; the narrow interstices are also marked each with a row of punctures equal to those of the striæ; in certain lights three rows of very indistinct foveæ may be seen in the usual position.

This species has also been reported from Washington and many localities in California.

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[1] LeConte, J. L. Report upon insects collected on the Survey. (Reports of explorations and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean. Made under the direction of the Secretary of War in 1853–1855. Supplement to v. 1. Zoological report no. 1.) 72 p., 2 pl. (p. 31, pl. 1, fig. 9). 1857.

CALOSOMA WILKESII Lec.

ORIGINAL DESCRIPTION.

Deep black, punctate, with thorax more than twice shorter than broad, narrowed posteriorly, sides quite rounded, margin somewhat reflexed, base broadly emarginate, posterior angles slightly produced, elytra nearly one-half longer than broad, not dilated posteriorly, rugose-punctate, with pits on both sides faintly marked in triple row. Length 0.65. Oregon. I have seen a specimen also in collection of the celebrated Exploring Expedition led by Charles Wilkes.

This species was described by LeConte[1] in 1851 and has since been reported as occurring in California, Idaho, Oregon, and Washington.

CALOSOMA LUXATUM Say.

ORIGINAL DESCRIPTION.

Brownish-black; elytra reticulate; head and thorax minutely punctured.

Inhabits Arkansas.

Mandibles flattened above, rugose, with oblique lines: head punctured: antennæ, second joint half as long as the third; thorax minutely punctured, punctures larger and confluent on the lateral margin; posterior angles rounded, extending backwards a little beyond the basal line; an impressed longitudinal line: elytra suborbicular, reticulate; longitudinal lines not more dilate or profoundly impressed than the transverse ones, which are not continuous, the points of intersection not distinguished by a puncture; the three punctured striæ obsolete, their traces hardly discernible in a certain light and not differently colored.

Length more than three-fifths of an inch.

This insect has the short, transverse thorax of Calosoma, but the proportions which the joints of the antennæ bear to each other are similar to those of many *Carabi;* the transverse lines are dislocated by the longitudinal ones.

Described by Thomas Say in 1823. Since that time several other species have been described which are generally considered as varieties of *luxatum.* Among these are *striatulum* Lec., *zimmermani* Lec., and *pimelioides* Walk. The former is undoubtedly a synonym of *luxatum* Say and the latter of *zimmermani* Lec. The writers have seen specimens of *Calosoma striatulum* Chev. from Arizona, which was described in 1835 by A. Chevrolat, habitat, Perote, Mexico.[2]

A few writers believe that some of those above-mentioned are distinct species[3] but the writers are unwilling to separate them in this way without having a large amount of material for comparison and study, and this is not available at present.

The bibliography is all listed under *C. luxatum* with a summary of the notes given on it and its varieties by various authors. It is the belief of the writers that a careful revision of this species and its so-called varieties should be made.

The writers feel, however, that a more complete series of specimens should be available for study before this is done, hence the whole is considered under *luxatum* and its varieties.

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[1] LeConte, J. L. Description of new species of Coleoptera from California. *In* Ann. Lyc. Nat. Hist. N. Y. f. 1851, v. 5, p. 125–216 (p. 200).

[2] The writers have received the loan of some material in this group from various entomologists of the United States, also have been in correspondence with Dr. E. C. Van Dyke, of the University of California, who has a large collection and who intends publishing later. The writers appreciate the need of detailed work in this group and give way to one who possesses the material for properly treating it.

[3] Col. Thos. L. Casey, in his "Memoirs on the Coleoptera IV" (Lancaster, Pennsylvania, 1913, p. 66–75), holds this view. He has subdivided the genus into Calosoma and Callisthenes, listing under the latter *luxatum* Say, *zimmermani* Lec., *striatulum* Lec., *pimelioides* Walk., *latipenne* Horn, and several new species and subspecies.

DISTRIBUTION.

Some of the museum and experiment-station collections of the United States contain numerous specimens of *C. luxatum* Say, *C. zimmermani* Lec., and *C. striatulum* Lec. Among the States and Territories where *C. luxatum* Say is reported as occurring are Arizona, California, Colorado, Indian Territory, Kansas, Montana, Nebraska, Nevada, Oregon, Utah, Washington, and Wyoming. Those for *C. zimmermani* Lec. are California, Kansas, Montana, Nebraska, Nevada, Oregon, Texas, Washington, Wyoming, and the Rocky Mountains without a State label. It is also reported from Canada. *C. striatulum* Lec. has been reported from Arizona, California, Colorado, Idaho, Kansas, Nebraska, Nevada, Utah, and Wyoming.

April 25, 1910, Mr. J. A. Hyslop of this bureau forwarded to the gipsy moth parasite laboratory several live beetles collected at Govan, Washington. One male and two females were placed in a jar of earth and fed larvæ of *Noctua clandestina* and *Malacosoma americana*. The females consumed 16 full-grown larvæ of the former and 3 of the latter species before May 24, when the last died. The male died in two days and did not feed.

BIBLIOGRAPHY.

1823. Say, Thomas. Descriptions of Coleopterous insects collected in the Expedition to the Rocky Mountains. Journ. Acad. Nat. Sci. Phila., T. III, 1823, p. 149–150.

Original description of *Calosoma luxatum*. Habitat, Arkansas.

1835. Chevrolat, A. Coléoptères du Mexique, Fasc. 7, p. 165.

Description of *Calosoma striatulum* from Perote, Mexico. This species has since been taken in Arizona, hence its inclusion here.

1848. LeConte, J. L. A descriptive Catalogue of the Geodephagous Coleoptera inhabiting the United States east of the Rocky Mountains. Ann. Lyc. Nat. Hist. N. Y., T. 4, 1848, p. 445.

Description of *Carabus zimmermani* from the Rocky Mountains.

1848. LeConte, J. L. A descriptive Catalogue of the Geodephagous Coleoptera inhabiting the United States east of the Rocky Mountains. Ann. Lyc. Nat. Hist. N. Y., T. 4, 1848, p. 445.

Short descriptive notes on *C. luxatum* giving its habitat as the River Platte.

1860. LeConte, J. L. The Coleoptera of Kansas and eastern New Mexico. Smithsonian Contributions to Knowledge, Vol. II, p. 4.

Original description of *Calosoma striatulum* from Milk River and Utah. The author draws very close comparisons with his new species to that of *C. luxatum* and *zimmermani*.

1866. Lord, J. K. Naturalist in Vanc. Island and British Columbia. Vol. II, 1866, p. 312.

Description of a new species (*Callisthenes pimelioides*) by Mr. Walker, but no locality given.

1881–84. Bates, H. W. Biologia Centrali-Americana (Col.) Vol. I, Pt. I, pp. 23, 262.

List of localities in Mexico where *C. striatulum* Chev. has been taken.

CALOSOMA LATIPENNE Horn.

ORIGINAL DESCRIPTION.

Allied to *luxatum* Say, but differs from all the races of that species in having a proportionately smaller head, broader thorax with more rounded sides and more broadly reflexed margin, apex less deeply emarginate, basal angles more broadly rounded; elytra more broadly oval, marginal groove deeper from the more strongly reflexed margin.

Color black and shining, head sculptured as in the smooth forms of *luxatum;* thorax moderately convex, disc smooth with the median line distinct with the sides coarsely punctured and wrinkled. Elytra broadly oval, smooth and shining, disc with approximate striae of very fine punctures, margin broad as compared with *luxatum* and equal in its entire length except at base, where it is narrower, rather densely muricately punctured and in well-preserved specimens of a greenish-bronze color. Under surface and legs black and shining almost entirely smooth and impunctured. Length 0.54–0.68 inch; 14–17 mm.

In most of the specimens before me the margins of the elytra immediately behind the humeri have three or four very distinct serrations. This character is quite common in the species of the *triste* group, but not seen in any of our species of the group *Callisthenes*.

On comparison the male of this species is found to be as broad as the female of *discors* Lec., the elytral margin broader and the surface sculpture of a different order.

Collected by Mr. Wm. M. Gabb and myself in the elevated regions of the South Sierras of California.

Described by Horn [1] in 1870. The species has later been taken by various collectors in several localities in California and in Reno, Nev.

CALOSOMA AUROCINCTUM Chaud.

(Syn.: *C. splendidum* Perbosc.)

ORIGINAL DESCRIPTION.

[Translation.]

Length 11–13 lines. This species is very distinct from the true *C. splendidum* Mannerheim, species from Haiti, as I have been able to convince myself by the examination of many individuals of each of the two species. *Splendidum* is of a beautiful uniform coppery green, while *aurocinctum* is of a metallic green, approaching blue, with the margins of the thorax coppery and those of the elytra of a brilliant coppery red. Head less heavily punctate; longitudinal impressions of the face much more marked. Thorax proportionately broader and more strongly rounded on the sides. Elytra less elongate, broadening more posteriorly; striæ less heavily denticulate; intervals less convex. Legs blue; the antennæ, mouth parts, legs, and tarsi which are reddish in *splendidum*, have a much darker color in *aurocinctum*. The habitat of this species is Mexico. I believe that it has nothing in common with *wilcoxi* Lec.

GENERAL NOTES.

This species was described by M. de Chaudoir [2] in 1850. The author bases his description on many individuals of this species collected in Mexico and compares it with *splendidum* Mann. from Haiti. Bates, in 1884, in his Biologia Centrali-Americana, listed *splendidum* Perbosc. as a synonym of *aurocinctum* Chaud.

Some years ago Mr. C. H. T. Townsend collected a specimen of *aurocinctum* Chaud. in Brownsville, Tex., which is deposited in the United States National Museum. The fact that a specimen has been taken in the United States is the reason for its mention here.

CALOSOMA DIETZII Schaef.

ORIGINAL DESCRIPTION.

Form of discolor, deep black, the reflexed elytral margin, base and sides of prothorax with a bluish reflection. Head sparsely punctate and very feebly rugose, epistomal impressions deep, causing a light convexity of the front; labrum angularly emarginate, rugose and impressed; mandibles stout, faintly rugose; antennæ nearly as long as the head and thorax, the outer joints at sides glabrous at base. Prothorax not quite twice as wide as long, widest before the middle, sides arcuate anteriorly, becoming nearly straight posteriorly, hind angles broadly arcuate and produced posteriorly, base slightly arcuate-truncate, apex broadly emarginate, with a broad, flattened, impunctured bead; disk moderately convex, basal angles feebly impressed and slightly reflexed, surface very feebly rugose, finely and sparsely punctate, the punctures larger at sides, coarser and more confluent in the basal region, median line fine. Elytra oval, not quite one-half longer than wide, very little broader than the thorax in its widest part, sides slightly arcuate, margin evenly and narrowly reflexed and coarsely rugosely punctate with a few granules intermixed; disk convex, striæ composed of fine, feebly impressed punctures, punctation of intervals finer and sparser; surface smooth. Length 15–18 mm.; width 7–8.5 mm.

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[1] Horn, G. H. Contributions to the Coleopterology of the United States. *In* Trans. Amer. Ent. Soc., v. 3, p. 69–142, pl. 1 (p. 70), 1870.

[2] Chaudoir, Baron de. Memoire sur la famille des Carabiques. *In* Bul. Soc. Imp. Nat. Moscou, t. 23, p. 349–460 (p. 420), 1850.

Tulare Co., Calif. Two males and two females in coll. Dietz which were mixed with typical *latipennis*.

This is the species referred to as *latipennis* by Major Casey in the remarks following the description of his *arcuata*. The true *latipennis* has a narrower thorax, similar to *luxatum*, different form of elytra, the humeri serrate and the elytral margin more narrowly reflexed near base than at apex.

C. dietzii is best placed near *discors*, which it more resembles than *latipennis*.

This species was described by Charles Schaeffer [1] in 1904.

CALOSOMA MAXIMOWICZI Mor.

[Pl. VII, fig. 9.]

ORIGINAL DESCRIPTION.

Obscurely greenish-coppery above, prothorax greatly rounded on the sides, somewhat narrowed posteriorly, but not contracted, elytra punctate-striate, interstices imbricately-grooved transversely, little dots impressed in series on the fourth, eighth and twelfth.

Female 27 mm.

Collected by Maximowicz on the way between Skabi and Ssawara.

This species was described in 1863 by A. Morawitz.[2] In 1883 it was reported by Bates at "Foot of the Komauotake; taken in abundance by shaking young oak trees."

In December, 1909, a dead beetle of this species was received from Rev. H. Loomis, Yokohama, Japan, and during the following summer a pair of beetles were received from Dr. Kuwana, but both died without feeding.

CALOSOMA SPLENDIDUM Dej.

ORIGINAL DESCRIPTION.

[Translation.]

Greenish, shining; elytra crenate-striate, small punctures impressed in triple rows; margin, tibiæ and tarsi black.

Length, 11½ lines; breadth, 5½ lines.

It resembles in form *scrutator*, but it is smaller, and its color dorsally of a beautiful metallic green, very shining. The head is proportionately smaller than that of *scrutator;* it has two very marked longitudinal recesses, between the antennæ, and it is covered with small sunken dots scarcely marked and not close to each other. The labrum, the mandibles and the palpi are black. The antennæ are missing in the only female individual which I possess. The eyes are brownish and very protruding. The thorax is less broad and less transverse than that of *scrutator;* it is narrowed posteriorly and covered with irregular wrinkles scarcely distinct; the longitudinal line of the middle is very marked; the posterior transversal impression is heavily marked, and it has on each side of the base a very distinct rounded impression; the anterior margin is truncate; the anterior angles are rounded; the sides are margined and somewhat recurved; the posterior angles are very pointed, and the base is deeply sinuate. The elytra have almost the same form as those of *scrutator*, and are striate and punctate in almost the same manner. The underside of the body and the legs are of the same color as the dorsum. The legs are of a sort of brownish-black. The tarsi are black. The mesothoracic legs are slightly arched; the metathoracic are straight.

It has been sent to me by Count Mannerheim under the name that I have kept for it, as coming from San Domingo.

It should be placed after *scrutator*.

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[1] Schaeffer, C. New genera and species of Coleoptera. *In* Jour. N. Y. Ent. Soc., v. 12, no. 4, p. 197–236 (p. 197), 1904.

[2] Morawitz, A. Beitrag zur Kaferfauna der Insel Jesso, v. 1, p. 20, pl. 1, fig. 7, 1863.

This species, type specimens of which were forwarded to Dejean from San Domingo by Count Mannerheim, was described by the former in 1831.[1] Dejean in his description gave Mannerheim as the authority for his new species, and the name of the latter has been erroneously quoted by many authors since that time.

According to recent writings of Mr. Chas. Schaeffer[2] this species has made its appearance in the United States and the following notes concerning its occurrence are copied verbatim:

> Two of the interesting additions to the coleopterous fauna of the United States, of which short descriptions are given below, were collected in Chokoloskee, southwestern Florida, and kindly given me by Mr. George Frank; the third: which I owe to the liberality of Mr. G. W. J. Angell, was collected at Enterprise, Fla., by C. W. Brownell.

A correction was added by the same author in 1910[3] to the effect that he had "reported this species wrongly from Enterprise, Fla. It was taken, as Mr. Angell informs me, in moderate numbers at lights in Key West, Florida."

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[1] Dejean, le Comte. Species Général des Coléoptères, v. 5, 883 p. (p. 558–559), 1831.

[2] Schaeffer, C. Three Cuban Coleoptera new to the fauna of the United States. *In* Jour. N. Y. Ent. Soc., v. 17, p. 148–150, 1909.

[3] Schaeffer, C. Additions to the Carabidæ of North America with notes on species already known. *In* Sci. Bul. Brooklyn Inst. Arts and Sci., v. 1, no. 17, p. 391–405 (p. 391), 1910.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 418

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER February 6, 1917

WESTERN YELLOW PINE IN OREGON.

By Thornton T. Munger, *Forest Examiner.*

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INTRODUCTION.

Western yellow pine[1] (*Pinus ponderosa* Laws.) is known throughout its range simply as pine or yellow pine, and in the lumber trade of the Northwest as western pine. It is sometimes called western soft pine or, more rarely, Oregon white pine. The terms used by California lumbermen are "western white pine" and "California white pine."

It is the most widely distributed pine in the United States and one of the most valuable. It is suited to a great variety of uses and throughout much of its range supplies nearly every local need. Its large size, good form, occurrence in large and easily accessible bodies, and the high technical qualities of its wood place it near the top of the list of commercially important American timber trees. The reported cut in the United States in 1915 was 1,252,244,000 feet, which places yellow pine seventh in rank if the oaks are considered collectively. California leads the States, with a cut (in 1915) of 389,991,000 feet, and Oregon is third with an annual output of 189,203,000 feet. There is estimated to be in the United States

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[1] Seven distinct species of pines occur naturally in the State of Oregon: (1) western white pine (*Pinus monticola*), the "Idaho white pine" of the markets, a valuable timber tree found in Oregon in rather limited quantities, chiefly in the mountains; (2) sugar pine (*Pinus lambertiana*), the important timber tree of California, which in Oregon occurs chiefly in the Cascades and other ranges in the southwestern part of the State; (3) white bark pine (*Pinus albicaulis*), a small, scrubby tree found on mountain tops throughout the Northwest; (4) knobcone pine (*Pinus attenuata*), a small tree of almost no commercial importance, which is found here and there in dry situations in the southwestern portion of the State; (5) lodgepole pine (*Pinus contorta*), also locally called black pine, jack pine, and shore pine, a small yet extremely hardy and aggressive tree that grows on both the coastal strip and nearly up to timber line on the mountains and covers vast areas of plateau in the central part of the State with pure stands of small trees; (6) Jeffrey pine (*Pinus jeffreyi*), a timber tree of the Siskiyou Mountains and California, which strongly resembles western yellow pine; and (7) western yellow pine (*Pinus ponderosa*).

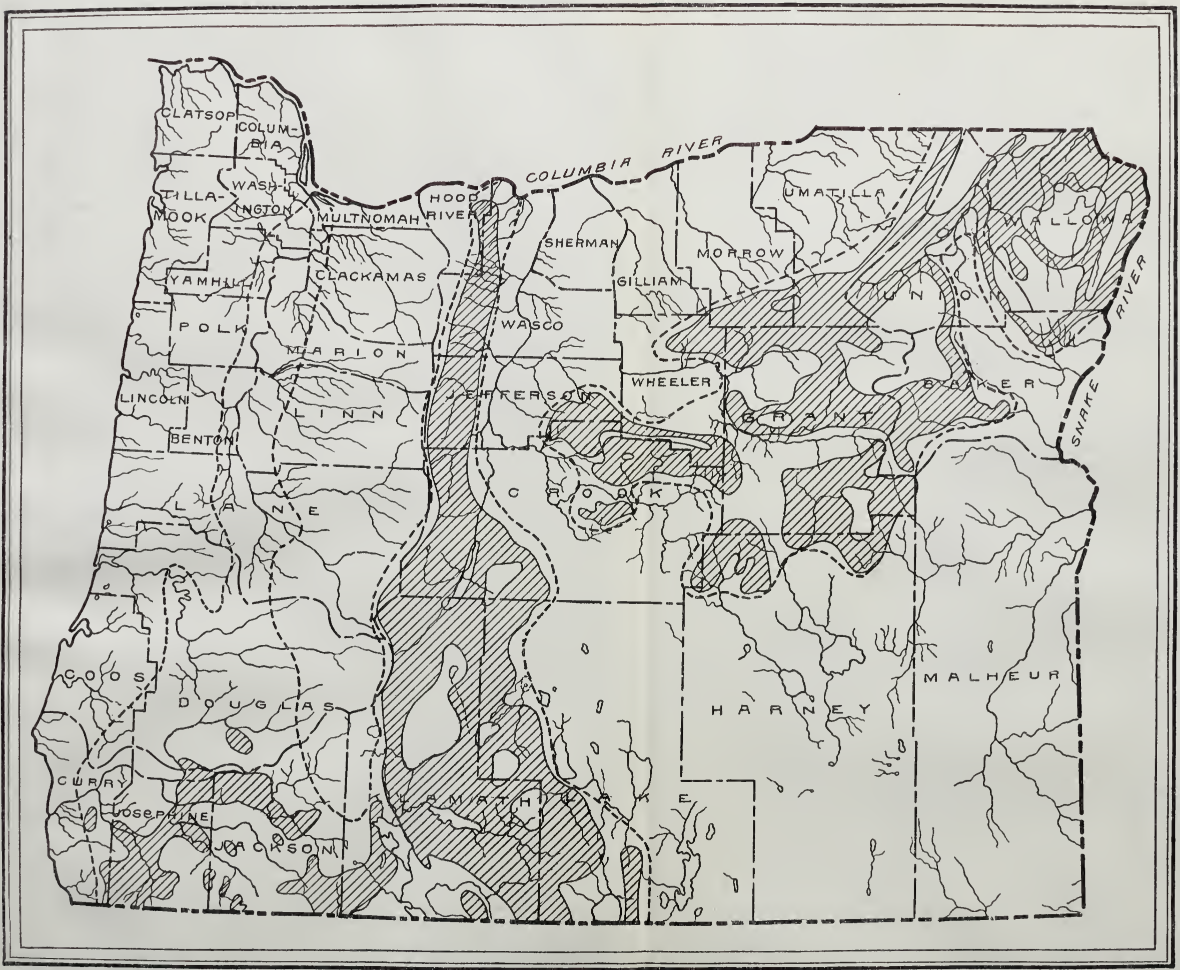
400,000,000,000 feet of this pine, more than there is of any other single species except Douglas fir. The annual cut is less than 0.004 of the stand.

Western yellow pine occurs naturally from southern British Columbia to Lower California and northern Mexico, and from the Pacific coast nearly as far east as to the one-hundredth meridian. It is found in the forests of every State west of the Great Plains, and in more than half of them it is the most important and valuable forest tree. In Arizona and New Mexico there is a western yellow pine forest which is said to be the largest continuous body of timber in the country.

DISTRIBUTION AND ABUNDANCE IN OREGON.

Of the 12 States in which western yellow pine occurs, California has the largest area of forests composed chiefly of this species, and Oregon comes second. Together these two States contain nearly 50 per cent of the area of commercial yellow-pine forests, and probably as large a proportion of the merchantable timber. Western yellow pine occurs on about 14,000,000 acres in Oregon, practically a quarter of the State and half of its timbered land. Of this area about 10,000,000 acres may be classed as commercial forest, the estimated stand amounting to 70,000,000,000 feet, or an average of 7,000 feet per acre, inter-forest waste areas included. Although the yellow-pine forests cover a larger proportion of the State than do the Douglas-fir forests, the fir stands are so much denser that the estimates show four times as much Douglas fir as they do yellow pine. The yellow pine amounts to from 15 to 20 per cent of all the commercial timber.

The distribution of yellow pine in Oregon is shown in Plate I. The areas of commercial forest, in which yellow pine forms at least 25 per cent of the stand and in which the quantity is large enough to be logged profitably, are shown in the shaded portions. The botanical range is indicated by a dotted line. The species is found from Bonneville on the Columbia River eastward to Idaho and southward to California through all the timbered portion of the State east of the Cascade Mountains. North of the Umpqua River and west of the Cascades it occurs only in small stands in the Willamette Valley. The altitudes at which it is found range from the lowest zone of forest growth on the borders of the sagebrush desert, the "dry timber line," which is at from 2,500 to 3,500 feet in eastern and central Oregon, up to 5,000 or 6,000 feet (scattered individual trees even going to 8,000 feet) on the slopes of the mountains. At this height the humidity is greater and the yellow pine gives way to a forest of moisture-demanding species. In the southwestern part of the State yellow pine occurs abundantly on the west slopes of the Cascade and Siskiyou Mountains, from the valley floors to altitudes of 6,000 feet, particularly in warm situations.



OREGON

▨ Commercial Forest of Yellow Pine

--- Limits of its botanical range

The important yellow-pine land of the State may be grouped into three sections: (1) The *Blue Mountain* region, embracing all the timbered land in the northeast quarter of the State, an area that is practically surrounded by treeless country and to a large extent consists of rolling hills; (2) the *eastern slope of the Cascades* and their outstanding ranges, a zone of mountain tops and plateaus, which is bordered on the west by the summit of the range and on the east by desert, and on which yellow pine forms 80 per cent of all the commercial timber; (3) *southwestern Oregon*, embracing the Siskiyou Mountains and the western foothills and slopes of the Cascades south of the Umpqua River. The timber in these regions is distributed as follows:

Regions.	Acres of commercial yellow pine.	Total stand in thousands of feet b. m.
Blue Mountains	4,276,000	31,350,000
East Slope Cascades	3,400,000	33,185,000
Southwest Oregon	2,330,000	6,830,000
Total	10,006,000	71,365,000

Most of Oregon's 70,000,000,000 feet of yellow pine occurs in 10 counties, each of which has over 1,500,000,000 feet b. m. and 300,000 acres of commercial yellow-pine timberland. In the order of the volume of their standing yellow pine, the counties are thought to rank as follows: Klamath, Crook, Lake, Grant, Jackson, Wallowa, Baker, Wheeler, Harney, and Union. Table 1,[1] prepared in 1912 and 1913, indicates the acreage and amount of yellow pine in private and in Government ownership for the counties in which it occurs in commercial quantities.

TABLE 1.—*Ownership and stand of yellow pine in Oregon, by counties.*

County.	Privately owned yellow-pine timberland.		Government yellow-pine timberland.[2]		Total	
	Acres.	*Feet b. m.*	*Acres.*	*Feet b. m.*	*Acres.*	*Feet b. m.*
Baker	213,168	1,536,000,000	306,064	1,345,000,000	519,232	2,881,000,000
Crook	535,346	6,847,900,000	638,115	6,415,000,000	1,173,461	13,262,900,000
Curry	59,520	45,400,000	493,721	55,300,000	553,241	100,700,000
Douglas						[3] 20,000,000
Grant	301,820	2,853,000,000	884,200	5,315,000,000	1,186,020	8,168,000,000
Harney	36,960	339,000,000	315,335	2,285,000,000	352,295	2,624,000,000
Hood River	6,000	18,000,000	4,000	12,000,000	10,000	30,000,000
Jackson	592,751	5,431,000,000	31,840	223,000,000	624,591	5,654,000,000
Josephine	773,927	721,600,000	363,327	296,800,000	1,137,254	1,018,400,000
Klamath	836,750	7,393,000,000	994,000	10,725,600,000	1,830,750	18,118,600,000
Lake	301,539	3,340,000,000	569,232	5,500,000,000	870,771	8,840,000,000
Lane					[4] 15,000	[4] 40,000,000
Morrow	112,200	777,000,000	25,000	143,000,000	137,200	920,000,000
Umatilla	32,200	275,000,000	35,000	233,000,000	67,200	508,000,000
Union	235,640	1,561,000,000	119,800	395,000,000	355,440	1,956,000,000
Wallowa	171,330	1,808,500,000	517,156	1,525,000,000	688,486	3,333,500,000
Wasco	40,000	280,000,000	145,000	920,000,000	185,000	1,200,000,000
Wheeler	198,875	1,586,000,000	101,690	1,101,000,000	300,565	2,687,000,000
Total	4,448,026	34,812,400,000	5,543,480	36,489,700,000	10,006,506	71,362,100,000

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[1] From a compilation prepared largely by Forest Examiner R. M. Evans on the amount, distribution, and ownership of yellow pine in Oregon.

[2] All within the National Forests except that which is within the Klamath and Warm Springs Indian Reservations and the small amount owned by the State.

[3] Estimated; occurs as scattered trees.

[4] Estimated; occurs chiefly as scattered trees.

DESCRIPTION.

Western yellow pine is a large, well-formed timber tree.[1] In old trees the bole is usually straight and full-formed. It is well cleared of dead branches, but usually clothed with live branches for from one-half to two-thirds its height. The maximum diameter is 8 feet and the maximum height 220 feet.[2] The largest tree measured in the course of a volume study of over 2,500 felled trees in various parts of Oregon was a little over 6 feet in diameter at breastheight and the tallest was 177 feet high. The usual size at maturity is about 3½ feet in diameter and 110 feet in height. Table 2 gives the prevailing height of yellow-pine trees of various diameters in two regions of the State, one near Lookingglass Creek, Union County, growing exceptionally tall, fine timber, and the other near the edge of the desert at Bend, Crook County, where the timber is short. Most of the yellow-pine timber of the State would fall between these two extremes.

TABLE 2.—*Average total height of several hundred trees of various diameters on two sites, one exceptionally good for tree growth and the other poor.*[1]

Diameter at breastheight.	Total height.		Diameter at breastheight.	Total height.		Diameter at breastheight.	Total height.	
	Lookingglass Creek. Union County.	Near Bend, Crook County.		Lookingglass Creek, Union County.	Near Bend, Crook County.		Lookingglass Creek, Union County.	Near Bend, Crook County.
Inches.	*Feet.*	*Feet.*	*Inches.*	*Feet.*	*Feet.*	*Inches.*	*Feet.*	*Feet.*
12	71	....	22	115	78	32	138	98
14	82	48	24	121	84	34	142	101
16	91	57	26	127	88	36	146	102
18	100	65	28	131	92	38	149	103
20	108	72	30	135	96	40	152	104

[1] In the Appendix are two volume tables which show the average contents in board feet of trees of various diameters and heights for two regions in Oregon. The average tree over 16 inches in diameter in the virgin stand contains about 1,000 board feet, and the average log about 250 feet. Trees with a volume of over 5,000 feet are very rare.

The bark of the trunk in young trees is dark gray-brown, roughly furrowed, and from 1 to 3 inches thick; in old trees it is tan colored (or "yellow"), is broken with rather large, irregular plates, and is commonly about 1 inch in thickness, and on very old trees even thinner. The crown is at first bluntly conical, but, as the tree matures, it becomes more and more roundheaded and bushy; on old trees it is quite flat-topped, and the upper branches are heavy and gnarled. The root system of mature trees consists of extensive, deep branching laterals which give the tree firm support. The foliage is not extremely heavy, so that the shade cast by yellow pines is not dense. The needles are usually from 4 to 6 inches long, on the best soils as long as 11 inches; and they are borne in clusters of three.

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[1] The forest characteristics of this tree vary decidedly in different parts of its wide range. The yellow-pine stands of the Black Hills are quite unlike those of the mesas of the Southwest, which are in turn unlike those of the eastern Oregon plateau or of the Sierra Mountains of California.

[2] Measured by John Muir in the Sierra Mountains of California.

The term "bull pine" is frequently applied to the younger yellow pines in an uneven-aged stand, usually those of rapid growth up to 18 or 20 inches in diameter and 100 or 150 years old. These immature, rapid-growing trees, or "bull pines," are quite different in appearance from the mature trees, or "yellow pines"; the bark of the young tree is much thicker, darker colored, and more furrowed; the crown s denser, longer, and more pointed; the wood is heavier, more sappy, and coarser grained; and the annual rings are more clearly defined. This has sometimes led to the belief that "bull pine" is a distinct species of pine, which it is not. Sometimes, particularly on wet soils, a tree will retain the "bull pine" characteristics to a considerable age and until it is 30 or more inches in diameter. The term "bull pine" is synonymous with the term "black jack," which is used in Arizona and New Mexico to denote young yellow pines; the relation between "bull" and "yellow" pine is analogous to that between "red fir" and "yellow fir" (the two types of the coast Douglas fir), or between "sapling pine" and "cork pine" (the two types of the Lake States white pine)

REQUIREMENTS.

CLIMATE.

Western yellow pine flourishes best in the heat and dryness of a continental climate, such as that on the interior plateaus and mountain slopes. In the north or on the highest slopes, where the growing season is cold, its development is much poorer than where the summers are long and warm. Though it shows a preference for sunny climates and warm situations, it can, however, endure severe winters and temperatures far below zero. In situations where it flourishes in central and eastern Oregon, the mean annual temperature goes as low as 42° F. and the mean summer temperature ranges from about 50° to 60° F., a maximum temperature of 100° F. being not uncommon.

Yellow pine will resist drought better than any other important commercial tree in the State. It forms splendid forests where the precipitation is only 18 inches a year and the summer dry season is long. Where the rainfall is but a little less than this the forest gives way to a treeless, sagebrush, or bunch-grass flora. Yellow pine also does well where the precipitation is much heavier—40 inches or more—but its development is by no means proportionately better in the wetter climates. It flourishes also in the mild, humid, insular climate of the Willamette Valley, which is almost the antithesis of that of the eastern Oregon yellow-pine ranges.

SOIL AND SOIL MOISTURE.

Western yellow pine grows and thrives on nearly every variety of soil within its range; it is one of the first trees to get a foothold on the disintegrating recent lava flows of central Oregon, and its ability to thrive on almost soilless steep talus slopes is remarkable. It grows also on loamy clay soils, on loose sand, and on the deep, light, fragmental pumice stone of central Oregon; but on cold, peaty, or heavy, moist soils, such as those adjacent to meadows, it is usually not found. It grows well on land which is too dry for any of its associates. It seems to prefer well-drained, loose soils; but an increase in moisture, provided the soil is well drained, makes for more rapid growth. Occasionally, but not usually, it grows on situations where the water table is within 4 or 5 feet of the surface during the growing season. It is, therefore, uncommon on flats and bottom land, and is distinctly a tree of the slopes. Exceptions occur, notably the form which occurs west of the Cascades in the Willamette Valley and which inhabits moist river benches.

LIGHT.

Stands of western yellow pine are always rather open because this tree is intolerant of shade. Seedlings do fairly well under the shade of parent trees, but saplings do not grow thriftily until they receive direct light. Western yellow pine is as intolerant as any of the trees with which it is associated in Oregon, and its reproduction can not compete successfully in the virgin forest with that of Douglas fir, white fir, or lodgepole pine on sites where the latter grow vigorously. With an increase in the amount of soil moisture, yellow pine becomes more tolerant of shade. The openness of most of the yellow-pine stands is probably due to the demand of the trees for soil moisture and the competition of the roots for ground space where moisture is insufficient, as well as to the demand for light and crown space.

REPRODUCTION.

SEED PRODUCTION.

Yellow pine after reaching middle age produces seed fairly abundantly. Trees under 50 years old, or 10 inches in diameter, rarely bear any cones; and large crops are not borne except by very much older and larger trees. Every three years, and sometimes oftener, come good seed years in which most of the adult trees in the stand bear seed; and in the intervening years there is usually some seed.[1] It is disseminated either by wind or by rodents that carry the cones or the seeds and store them. Sometimes many bushels of cones are found in a squirrel cache. Undoubtedly a considerable proportion of the seed crop is eaten by animals, since the seed is large and attractive. In Oregon, yellow-pine seed is larger than it is farther east. The number of seeds to the pound from eastern Oregon trees is between 8,000 and 9,000. A bushel of unopened cones will usually yield about 1½ pounds of seed.

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[1] For a full discussion of seed production of the yellow pine of the Southwest, see Forest Service Circular 196, "The Influence of Age and Condition of the Tree upon the Seed Production in Western Yellow Pine," by G. A. Pearson.

GERMINATION.

The seed germinates fairly freely, but in Oregon not until the spring following its dissemination. Laboratory tests of clean seed show that from 60 to 85 per cent of it is fertile, and that most of it germinates between four and eight weeks after sowing.

Field studies indicate that young seedlings are most abundant in the exposed spots in the forest, such as on scabby ridges, where the mineral soil is naked. Here germination may be the best, but the mortality of the seedlings the first year is the largest.

In certain parts of Oregon, particularly on the very dry pumice soils of the upper Deschutes Basin, it is noticeable that a very large proportion of the seedlings come up in clumps, from 2 to over 50 being crowded into a space as large as a half dollar. It has been suggested that these clumps originated where a cone accidentally became buried. But such is not the case in this particular locality. They have come from bunches of seed which were buried by provident chipmunks. (See Pl. II.) Some counts made in Crook County of the reproduction in the forest showed that 85 per cent of all the 1-year-old seedlings were in these chipmunk-sown groups. Much more seed must be sown broadcast by the wind on the surface than is accidentally left in these chipmunk caches, yet it is evident that the seed which is buried has a very much better chance of germination than that which lies on the surface. This is particularly so on the drier and looser soils, where the chipmunks may actually be considered an aid to reproduction. The competition in growth between the seedlings in these clumps becomes very keen early in their lives and they thin out rapidly, though it is not unusual to find ten or a dozen seedlings four feet high growing from a single hole. One unusual instance was noted where 29 fourteen-year-old saplings were living in a cluster. One-year-old seedlings in these chipmunk-sown clumps have been found to be less likely to succumb to drought than solitary seedlings, perhaps because they give each other protection.

It is not infrequent to find a dense row of seedlings, a veritable natural hedge from 25 to 75 feet long, located in the path of mineral soil and ashes left after a fallen tree had burned up. The cause of these hedges is not perfectly understood.

DEVELOPMENT OF SEEDLINGS.

Although seedlings start with considerable vigor after each good seed year, their mortality during the first year is exceedingly high. In the early summer the forest floor is sometimes thickly dotted with freshly sprouted seedlings, while on the same area the next year, as a consequence of the summer drought and the winter ground heaving, there will be but an occasional living seedling. A count of the seedlings on 67 small sample plots distributed over five acres, in the fall of 1910 (after the excellent seed crop of 1909 and the very dry season of 1910), showed that 79 per cent of the seedlings which started that spring had died by fall.[1] Probably not one seed in ten escapes the birds and rodents; and, of those that do germinate, probably as many are killed by late frosts immediately after germinating or by frost-heaving the first winter or by drought the first summer. It is estimated that in eastern Oregon hardly more than one seedling in a hundred lives to be 2 years old. After the first year the mortality from drought is very slight.

The year-old seedlings seem to do best beneath the partial shade of the mother trees, probably because of the protection which they are afforded against drying sun and winds, and perhaps against frost as well. Older seedlings do not do well in dry places directly beneath old trees, because of the absorption by the roots of the latter of all the available soil moisture; the seedlings that ultimately succeed are those in the gaps between the clumps of old trees or beneath those which have recently died. For some reason those in the latter situation are particularly flourishing in eastern Oregon. On dry soils, clumps of brush and mats of squaw-carpet (*Ceanothus prostratus*) seem to assist yellow-pine reproduction, probably by their effect in conserving the soil moisture.

For these reasons and for other causes which are not thoroughly understood, yellow-pine reproduction is extremely patchy in the virgin forest; here there will be almost a thicket of young trees, and near by, under seemingly similar conditions, there will be little or no reproduction.

In dry situations bordering the limit of yellow-pine growth, the reproduction seems to be greatly benefited by the protection that bushes afford, and it is conspicuously more abundant on the sheltered north side of clumps of bushes than elsewhere. An examination [2] of an area adjoining the desert in Crook County showed the following interesting results: Of all the yellow-pine seedlings 70 per cent were on the north side of sagebrush and bitterbrush bushes, 13 per cent

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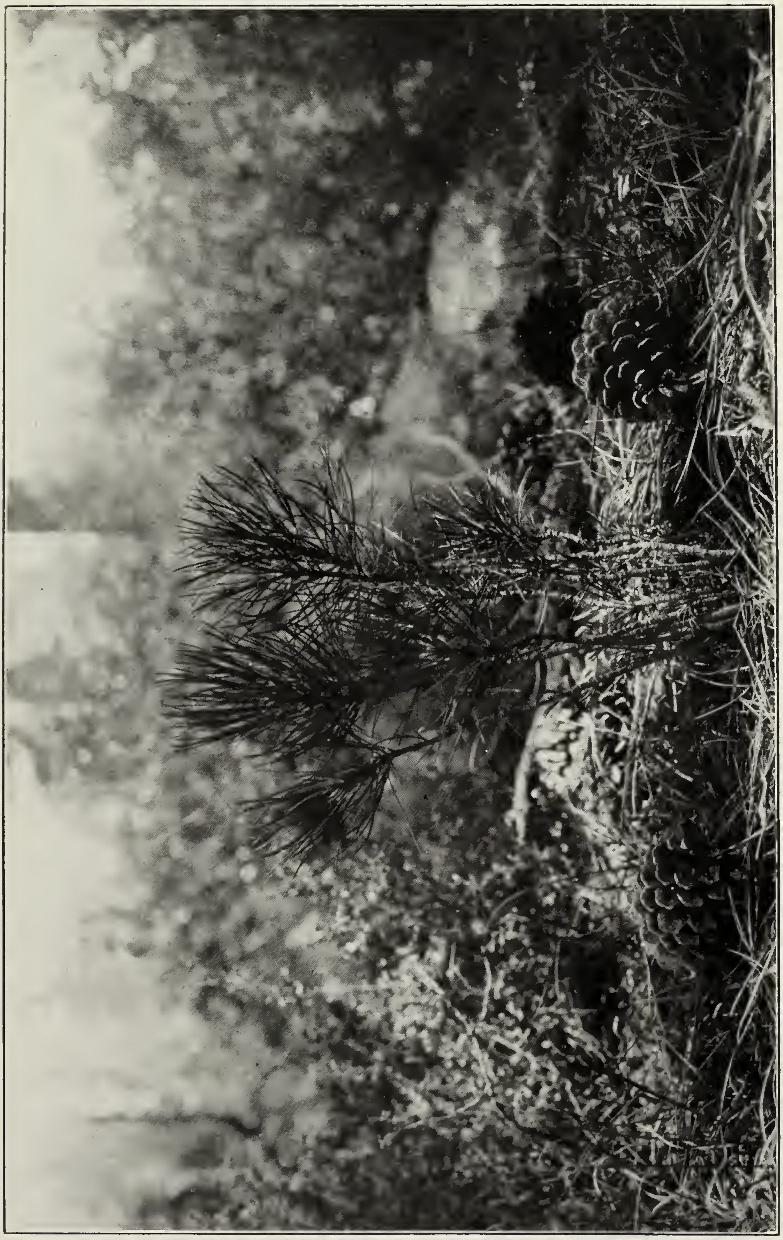
[1] Manuscript report, "Western Yellow Pine Reproduction," by George A. Bright, forest assistant.

[2] Manuscript report by Forest Supervisor M. L. Merritt, "Occurrence of Western Yellow Pine Seedlings in Openings in the Edge of the Deschutes National Forest, Bordering on the Desert."



A CLUMP OF WESTERN YELLOW-PINE SEEDLINGS ABOUT 6 YEARS OLD, GROWING FROM A CHIPMUNK'S STORE OF SEEDS.

were on the south side of these bushes, 11 per cent were sheltered by logs or lodgepole pines, and only 6 per cent were in the open, although these open spots occupied a considerable proportion of the area.

In the Blue Mountains the reproduction of yellow pine is very abundant, both in the virgin forest and after cuttings. Perhaps it is more prolific here than anywhere else. In this region where an area has not been burned over by a surface fire for a number of years, there is quite commonly a veritable thicket of little trees from a few inches to several feet high. Actual counts have shown that there are sometimes 14,000 seedlings on a single acre, the ages ranging from 13 to 21 years.

The first season most of the growth of the seedling is below ground; it forms a top only 2 or 3 inches high with a small tuft of short needles, but it grows a taproot from 7 to 12 inches long in its effort to reach subsoil moisture. The second year more of a top is formed, but growth is slow for at least four years, and does not become rapid in any event until the seedling has abundant light.

Table 3 gives an idea of the rate of growth of the dominant seedlings in average yellow-pine forests in the Blue Mountains, which is closely similar to the average growth of seedlings in other forests of central and eastern Oregon. In making this table only seedlings which had free growing space and looked as though they would live at least to the pole stage were included. The growth of even these dominant seedlings is exceedingly slow during their first 20 or 30 years.

TABLE 3.—*Seedling height growth, Blue Mountains, Oreg.*

[Based on 1,182 measurements.]

Age.	Height.	Age.	Height.	Age.	Height.
Years.	*Feet.*	*Years.*	*Feet.*	*Years.*	*Feet.*
1	0.2	5	0.8	9	1.5
2	.3	6	1.0	10	1.7
3	.5	7	1.1	15	2.7
4	.6	8	1.3	20	4.0

EFFECT OF FIRES.

Western yellow pine is classed commonly as a fire-resistant species, probably because in its open stands destructive crown fires are rare; but it is by no means immune to damage by fire. Occasionally a fire gets into the tops of the trees in a pure yellow-pine forest on a slope and sweeps over the whole hillside, perhaps a square mile in extent, killing all the trees in its path. This spectacular form of fire damage is uncommon, however; by far the greatest amount of damage is done by surface fires which work in an inconspicuous way. Light, slowly spreading fires that form a blaze not more than 2 or 3 feet high and that burn chiefly the dry grass, needles, and underbrush start freely in yellow-pine forests, because for several months each summer the surface litter is dry enough to burn readily. Practically every acre of virgin yellow-pine timberland in central and eastern Oregon has been run over by fire during the lifetime of the present forest, and much of it has been repeatedly scourged.

It is sometimes supposed that these light surface fires, which have in the past run through the yellow-pine forests periodically, do no damage to the timber, but that they "protect" it from possible severe conflagrations by burning up the surface débris before it accumulates. This is a mistake. These repeated fires, no matter how light, do in the aggregate an enormous amount of damage to yellow-pine forests, not alone to the on-coming young trees, but to the present mature merchantable timber. This damage may be classified under several headings:

(1) The fire-scarring of the butts of merchantable yellow pine.

The bark of yellow pine in this region is not particularly thick at the base, and surface fires find no difficulty in eating through it and getting at the inflammable wood of the butt. A careful cruise of every tree on 154½ sample acres in typical yellow-pine stands in several localities in the Blue Mountains showed that 42 out of every 100 trees were fire-scarred—i. e., the wood was exposed because the bark had been burned off. Their susceptibility to fires is aggravated by the work of the red turpentine beetle (*Dendroctonus valens*), which, by working in the cambium at the base of the tree, loosens patches of bark and stimulates the flow of pitch. These fire-scarred trees may easily fall a prey to the next fire that runs through the forest, and some of them are so deeply scarred at the base that they are likely to be windthrown. It is noticeable that especially the larger (and therefore the older) trees are fire-scarred, because they have been exposed to more of these periodic fires. A record of 1,184 representative trees cut in a logging operation in Grant County shows that 22.8 per cent of the butt logs were fire-scarred (still more of the trees may of course have had scars which did not show on the log because the stumps were cut high enough to avoid them), and that 18.6 per cent of the butt logs were so badly fire-scarred that about 46.1 board feet per log (equivalent to 14 per cent of the full scale of the defective logs) was lost and had to be deducted from the full scale.

(2) The killing of occasional trees by the burning through of the base.

Though these surface fires kill very few trees outright by the intensity of their heat, yet each fire—even the lightest grass fire—is apt to cause the death of a yellow-pine tree here and there by gnaw-ing it off at the base with a smoldering flame. An examination of a great many burns in eastern Oregon shows that an average surface fire, on land which has been periodically burned over before, kills in this way one merchantable tree on from 1 to 4 acres. The average number on 130 sample acres examined in detail was one tree to every 1.12 acres. This is not a large number of trees, and they are so scattered about in a burn as not to be conspicuous; but in the aggregate it is an enormous loss, especially as each of the repeated fires may kill the same number, and the trees felled by these surface fires are usually the larger ones.

(3) The "pitching" of the butts of commercial trees.

Trees that are fire-scarred or which have been excessively heated about their bases are very apt to become "pitch-butted;" i. e., a great deal of "fat" pitch is deposited in the wood in the lower part of the stem. This pitch greatly lessens the value of the log for lumber because excessive pitch is a defect which bars lumber from the best grades on the market. A tally of 1,184 butt logs in the Blue Mountains shows that 25 per cent of them are "pitched" and that the average diameter of the pitchy area on the basal cross section of the log is 14.7 inches. This indirect result of surface fires is not conspicuous, but is a very real source of loss.

(4) The impoverishment of the soil by repeated burnings.

Frequent fires consume the vegetable matter, which should be allowed to accumulate and decay and thereby better the physical condition and add to the fertility of the soil.

(5) Destruction of the reproduction which should form the basis for the next crop.

Each fire kills the seedlings and some of the saplings, so that, if the fires are of frequent occurrence, no young growth has a chance to replace the mature trees that die from natural causes. Yellow pine normally occurs in Oregon in uneven-aged stands in which trees of all ages are in intimate mixture; frequent fires prevent the stand from having the proper number of young trees. If this process is continued long enough, it will annihilate the yellow pine by gradually killing off the old trees and at the same time preventing the survival and maturity of any young ones. This very thing has happened in places in the Siskiyou Mountains and southern Cascades. Here areas once covered by fine stands of yellow-pine timber are now treeless wastes, covered only by brush or mock chaparral.

(6) Degeneration in the forest type.

In certain parts of the State repeated surface fires have the effect of transforming the forest type from a stand consisting largely of yellow pine to one consisting of lodgepole pine, whose reproduction is extremely abundant and vigorous after fire.

Table 4 shows strikingly the damage that ordinary surface fires have done to the yellow-pine timber in several instances in various parts of Oregon:

TABLE 4.—*Damage done by surface fires to merchantable yellow pine over 12 inches in diameter.*

[Average of 156 sample acres distributed over four typical fresh burns in Oregon.]

Locality.	Percentage by number of trees in each class.			Apparently uninjured.
	Burned to death.	Felled by fire.[1]	Scarred by fire.[2]	
Lava Butte fire, 1911, Deschutes National Forest	3.2	0.8	31.9	64.1
Medical Springs fire, 1910, Minam National Forest	(3)	6.8	43.2	50.0
Big Minam River fire, 1910, Wallowa National Forest	(3)	3.2	46.9	49.9
Devil's Run fire, 1910, Wallowa National Forest	2.7	2.3	45.5	49.5

[1] The figures in this column would be fully twice as large if the percentage by volume of the trees that were killed, instead of the number, were taken, since it is chiefly the larger trees that are felled by fire.

[2] This column includes also trees that were scarred by previous fires, since it is impossible to distinguish those scarred in the last fire from those previously injured.

[3] On these burns the trees which were actually killed by the intense heat of the fire were not distinguished from those killed by being felled by the fire eating out basal fire scars.

SOURCES OF INJURY OTHER THAN FIRE.

INSECTS.[1]

Next to fire, insects are the most destructive enemies of yellow pine. Hardly a square mile can be found in the State in which there is not fresh evidence of insect damage to the living timber. There are many insects, chiefly boring grubs, that work in dead or dying yellow-pine trees and in yellow-pine lumber, but relatively few that attack the living tree. In Oregon there are but three species important enough to interest the forester and timberland owner; one of them is a defoliator and the others are bark beetles. The defoliator is the "pine butterfly" (*Neophasia menapia*), a small white moth, which, when in the caterpillar form (the caterpillars are black, with bright green markings, and are about 1½ inches long at maturity), feeds upon the needles of yellow pine. Sometimes the foliage on a tree is almost all eaten off and the tree suffers severe damage or, if the defoliation is repeated, death. This insect is found to some extent in various parts of Oregon, but so far as known it is not now doing any great amount of damage. There have been a number of serious infestations of the insect elsewhere, notably in Yakima and Chelan Counties, Washington, where yellow-pine timber over a considerable area was killed. It is a pest which is decidedly dangerous when it becomes abundant.

There are a large number of species of bark beetles which are more or less harmful to living yellow pine, but only two of them are particularly important in Oregon, the western pine destroyer (*Dendroc-*

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[1] See Department of Agriculture, Bureau of Entomology, Bulletins 32; 38, pt. 2; and 83, pt. 1; and Circulars 125, 126, 127, and 129, for full description of these insects.

tonus brevicomis) and the mountain pine beetle (*Dendroctonus monticolæ*). These insects kill the trees which they infest by eating the soft inner bark and cambial layers, thereby girdling the tree. Colonies of the former are found here and there scattered through the yellow-pine region. Each colony kills a tree or two each year, but ordinarily shows no tendency to spread. A group of infested trees is usually characterized by from three to ten or more dead trees in a clump, some of which have apparently been dead several years, some a shorter period; and if the colony is still at work, by one or two reddish-topped trees. The bark of some of the trees commonly shows holes where woodpeckers have worked to get at the insects.

The inordinate multiplication of the insects is prevented by their natural enemies, so that usually they are found only in what may be called the normal infestation. Under exceptionally favorable conditions, possibly climatic, or as a result of a decrease in the number of their enemies, these insects may become at any time manyfold more plentiful; and if they do, they may kill an enormous amount of timber. They work chiefly in large, old trees, most frequently those which have been damaged by fire, by lightning, or otherwise. The damage that they do is inconspicuous because it is scattered, but in the aggregate it amounts to a great deal.

The mountain pine beetle has shown itself to be the worst insect enemy of yellow pine in Oregon. Colonies occur in greater or less abundance in the forests of the whole eastern part of the State, usually working in lodgepole pine. Recently it has been spreading with alarming rapidity through the lodgepole-pine forests on the upper slopes of the Blue Mountains, particularly on the Wallowa and Powder River Mountains, so that within the past few years 500,000 to 600,000 acres in these mountains have been attacked and more than half the lodgepole-pine trees on at least 300,000 acres have already been killed. Four or five years ago the insects extended their ravages to the yellow pine adjacent to the infested lodgepole pine and a good deal of it was killed. Had the infestation continued to spread in the yellow-pine timber as it began, the damage would have been enormous, but within the last two years it has subsided very greatly, evidently having been regulated in time by natural causes. These infestations evidently have their ups and downs and through some natural agency, imperfectly understood, subside and regain their normal balance. This bark beetle prefers to work in the smaller yellow pines, but at times attacks the largest and thriftiest old trees. Extensive operations in felling and barking infested trees have been conducted by the Forest Service and by individual owners in the Blue Mountains under the direction of the Bureau of Entomology, with the purpose of checking the spread of this pest; but definite conclusions as to the effectiveness of this work have not yet been reached.

VEGETABLE PARASITES.

The most harmful of the vegetable parasites is a kind of mistletoe (*Razoumofskya campylopoda*) which is, in some localities, very abundant. This plant attaches itself to the little twigs and causes in them, as they develop, swellings and deformities ("witches' broom"), both on the main stem and the twigs. It kills single branches outright, but seldom causes the death of a tree; it may, however, weaken the tree's vitality and impair its value for commercial purposes. A rust called *Peridermium filamentosum* causes, on the twigs, swellings which are quite conspicuous in yellow-pine young growth. Yellow pines, especially in the Blue Mountain region, as well as some of their associates, are often heavily covered with two lichens—*Alectoria fremontii*, "black moss," and *Evernia vulpina*. These plants are not fatal, but may injure the host trees by shading their foliage and preventing proper bark shedding and aeration.

Yellow pine is rather free from fungi which cause decay in the wood. One of its worst enemies among the fungi is *Polyporus schweinitzii* (butt rot or dry brown rot), which gains entrance through basal scars and damages particularly the lower portion of the tree. It is, like most forms of decay, a disease which affects old, overmature timber, and seems to be particularly abundant on situations where the soil is sterile or thin. It is usually difficult to tell from the outside appearance of a tree whether it is affected with butt rot. Another bad form of decay is *Trametes pini* (ring-scale fungus, pipe rot, or white-pitted rot), which enters the tree at broken tops or in bad wounds on the stem and rots out the heartwood. The presence of *Trametes pini* can usually be detected by the thin, unhealthy bark and the "bumpy" stems of seriously affected trees. *Fomes laricis* (chalky quinine fungus, or sap rot) is a third serious fungous enemy of yellow pine. It causes a red heart rot with felts of white mycelium.[1] Its fruiting bodies are generally very large, round, hoof-shaped, with a rough white, chalky surface.

The amount of decay in yellow-pine timber caused by these fungi is of course very variable; some thrifty stands are almost free from it, and in others it is very bad. On one tract of very overmature timber in central Oregon a third of the trees had to be long-butted from 4 to 6 feet each to get rid of the worthless portion of the first log. The scale of over 2,000,000 feet of logs cut in the Blue Mountains shows that only 0.9 per cent had to be subtracted from the full scale on account of rot. In addition, some worthless trees or portions of trees were left in the woods. This would probably indicate for this particular tract an amount of defect on account of rot equivalent to about 2 per cent of the total stand.

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[1] U. S. Department of Agriculture, Forest Service Bulletin (unnumbered), "Forest-tree Diseases Common in California and Nevada," by E. P. Meinecke.

As is the case with other pines, freshly cut logs and lumber are apt to "blue" if not kept under water or dried soon after cutting; and the blue stain decidedly lessens their commercial value. The stain is caused by *Ceratostomella pilifera*[1] and other fungi.

THE ELEMENTS.

Yellow pine grows in a climate in which it is especially exposed to high winds, drought, severe winters, frost heaving, and lightning. The fact that it is able to survive as well as it does while other species can not is an indication that it is fairly immune to damage by these agencies.

It is, comparatively speaking, a windfirm species, and normally is able to stand without the protection of surrounding trees. Sometimes in the virgin forest a good many windfalls are found, but these are the result of an exceptionally high wind at a time when the trees were least able to withstand it, either because they were snow-laden or because the ground was wet. A recent storm in the Blue Mountains, such as is experienced in this region every year or two, blew down in a certain locality one tree to each 5 acres. The tornado of 1894 mowed down all the timber in its path for a mile or more, the yellow pines succumbing to its force as well as all other trees. Where a part of the stand has been removed by cuttings, the trees which are left are more liable to windthrow than they were in the virgin forest. On one tract of 1,624 acres in Grant County, 1,600 trees over 12 inches in diameter were thrown in the first two years after a partial cutting.[2] This is undoubtedly an exceptional instance, for similar areas of equal exposure have at the same time suffered merely a nominal amount of windthrow. In heavy winds no class of tree in partially cut-over areas seems to be entirely immune to windthrow, though the risk increases with the height of the tree and the density of its crown. Where the trees are in groups, the wind damage is considerably greater than where the reserved trees are evenly distributed. The effect of the winds is particularly severe in a solid body of uncut timber along the lee edge of a cut-over area.

Drought, of course, is a factor which limits the local distribution of this tree, for the yellow-pine forests in Oregon all abut on territory which is too dry for their growth. Drought seems to affect the reproduction chiefly, by preventing it from gaining a foothold on dry soils. After the sapling stage is passed, it is rarely killed by drought, though of course excessive drying of the soil affects the growth of the tree unfavorably.

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[1] "The 'Bluing' and 'Red Rot' of Western Yellow Pine," by Herman von Schrenk, Bull. 36, Bureau of Plant Industry, U. S. Dept. of Agriculture.

[2] Manuscript report, "Windfall Damage on Cut-over Areas," by R. E. Smith, forest examiner, and R. H. Weitknecht, assistant forest ranger.

Drought in combination with severe winter weather, particularly desiccating winds at a time when the ground is frozen after a dry autumn, sometimes does a good deal of damage to yellow pines in exposed situations. It occasionally happens that strips of timber adjoining the open country or in other particularly bleak and dry situations turn brown in the winter or early spring, all the old needles fall, and the trees are apparently winterkilled, but leaf out as usual after the growing season begins. To this form of injury the name ''red-belt disease'' has been given. Yellow pine does not suffer any more than its associates, and possibly less than Douglas fir. In the winter of 1909 the foliage on several thousands of acres in Morrow County (and to a less extent in Crook and Grant Counties), chiefly on the north slopes adjoining the open country, turned brown, and the trees were apparently winterkilled, but recovered and seem to be in no way permanently injured.

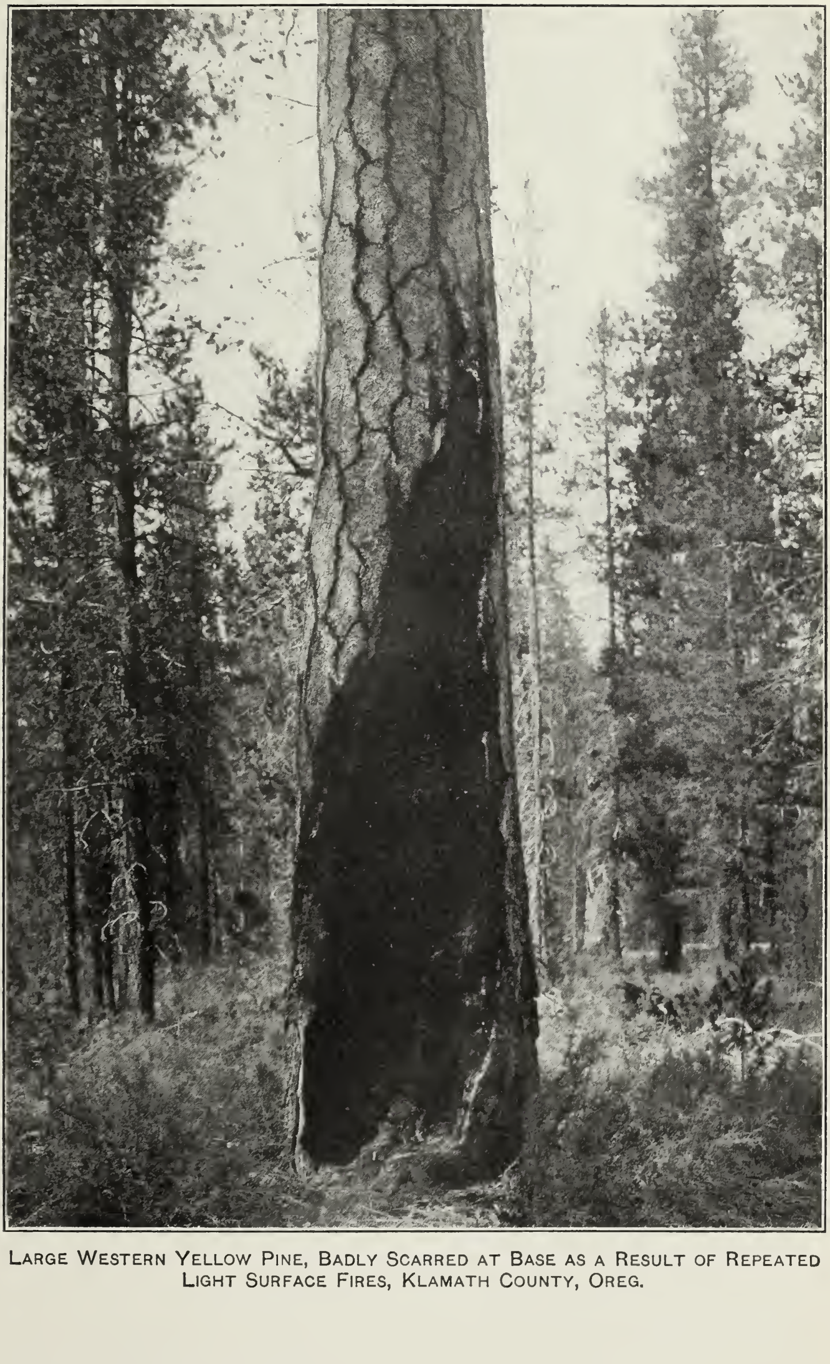
''Spike-top,'' or ''stag-headedness,'' is commonly an indirect result of drought, and is usually an accompaniment of old age. In the virgin stands of yellow pine in Oregon, as elsewhere in this tree's range, there is a good deal of this defect, often from 10 to 15 per cent of the merchantable trees being affected. This is natural, since in the primeval forest such a large proportion of the trees are very old and past maturity. ''Spike-top'' considerably reduces a tree's value, both because the dead tip of the tree is worthless and because it is an entering place for decay.

In certain regions, particularly on tne pumice soils of central Oregon, the soil in the forest ''heaves'' in the spring and autumn and lifts young seedlings out of the ground. This occurs here to such an extent as to make it difficult for reproduction (either natural or planted seedlings) to get a good start; some of the seedlings are killed outright, and many do not recover for years from the root injuries which they receive when young.

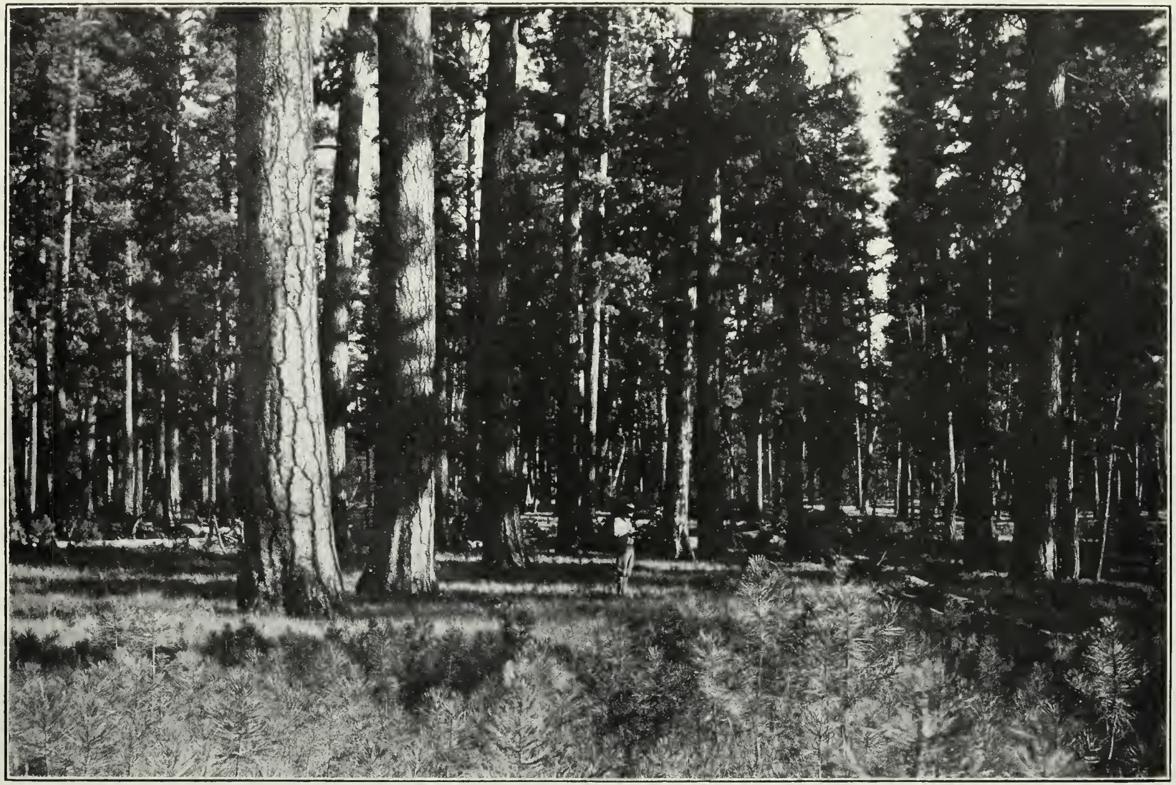
Thunder storms are not infrequent in the Cascade and Blue Mountain regions of Oregon, and often yellow pines are struck by lightning. They are then scarred in such a way as to detract from their commercial value and occasionally are shattered or killed outright. It is not unusual for a group of half a dozen trees to be struck at the same time, so that the ground over half an acre is littered with chunks of bark and splinters.

ANIMAL LIFE.

Yellow pine suffers comparatively little injury from animals. Porcupines and other rodents gnaw the bark of saplings and small poles, and occasionally seriously damage or kill them. Sapsuckers and woodpeckers seem to confine their activities chiefly to dead and insect-infested trees of this species and do no damage to the wood; in fact, they undoubtedly do a great deal of good by destroying harmful insects.



LARGE WESTERN YELLOW PINE, BADLY SCARRED AT BASE AS A RESULT OF REPEATED LIGHT SURFACE FIRES, KLAMATH COUNTY, OREG.



EXCELLENT STAND OF WESTERN YELLOW PINE IN GRANT COUNTY, OREG.

Showing the variety in size and age of the trees, the openness of the forest, the plentiful herbage beneath the trees, and the abundance of seedlings in groups, characteristic of Blue Mountain timber.

Since yellow-pine forests are grazed over by sheep and cattle, the reproduction is somewhat exposed to damage by these animals, particularly by sheep, which trample a good many seedlings when close herded. Sheep also, when short of forage, as along driveways or near bed grounds, browse on them in such a way as to deform the seedlings permanently. If the range is not overstocked and the sheep are properly handled, they will not, in Oregon, do any appreciable damage to the yellow-pine young growth in the forest at large; trees over 6 feet high are practically immune from damage.

In some parts of the State, particularly in Klamath County, are found here and there large trees upon which are great scars, from 3 to 7 feet above the ground, half encircling the tree. (See Pl. III.) These scars were caused years ago by Indians who, in the springtime, stripped the bark in order to get at the mucilaginous layer of forming wood, which they scraped off and used as food.[1] The scars make the trees vulnerable to light surface fires and detract considerably from their merchantable value.

CHARACTER OF THE STANDS.

Yellow pine is fundamentally a gregarious tree; that is, it is a tree which does best and is found most commonly in pure or nearly pure stands. Most of the forests of Oregon in which it occurs commercially are at least 75 per cent yellow pine, and the other trees that are present in the mixture are apt to grow in groups by themselves and not in intimate mixture with the pine. One reason why yellow pine occurs so largely in pure stands is that it will grow and form fine forests in situations on the plateaus and south slopes that are too dry and hot for other species, and being a rather unsuccessful competitor of the more tolerant species, Douglas fir, white fir, and lodgepole pine, it is largely excluded from soils moist enough for these species to thrive in. It does occur, however, in mixture with other species in almost every degree.

In most of the pure yellow-pine forests of the State the trees are spaced rather widely, the ground is fairly free from underbrush and débris, and travel through them on foot or horseback is interrupted only by occasional patches of saplings and fallen trees. (See Pl. IV.) The forests are usually not solid and continuous for great distances, except along the eastern base of the Cascades, but are broken by treeless "scab-rock ridges," or natural meadows. On the north slopes, in draws, or in other places where mixed with other species, the yellow-pine forests are usually denser, more brushy, and therefore harder to traverse. Toward the limits of the forests adjoining the desert the stand is confined usually to a fringe of trees along the canyon sides, to draws, and to the north hillsides, the intervening drier and more exposed areas being treeless. Instances are seen here and there where an advance guard of young yellow pines is progressing from the forest into the desert, indicating that the limits of the yellow-pine forest are being extended in places. Bordering the desert it is often in mixture with western juniper (*Juniperus occidentalis*). At the upper altitudinal limit of its distribution the typical yellow-pine forest gives way rather suddenly to a very different, much denser stand of other species.

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[1] Sargent's Silva, XI, p. 82.

ASSOCIATES.

The associates of yellow pine in mixed stands are variable, and depend upon the locality. In the Blue Mountains western larch (*Larix occidentalis*) is its usual companion and grows with it in an intimate and harmonious mixture. In the moister situations white fir (*Abies concolor*) is a common associate, as is also Douglas fir (*Pseudotsuga taxifolia*) in most parts of the State. All of these species occur to a large extent in groups by themselves; in the Blue Mountains it is common for the south slopes to be covered with a fine stand of yellow pine, while the north slopes are covered almost entirely with larch, white fir, and Douglas fir. Lodgepole pine (*Pinus contorta*) is another common member of the mixed forests, particularly along the eastern slopes of the Cascades. It is a thrifty and militant species, and has the ability to occupy burns to the exclusion of all others. With the help of periodic surface fires, which have encouraged its reproduction and at the same time discouraged the reproduction of yellow pine, it has been able to encroach upon land where yellow pine might be growing.

On the southern Cascade and Siskiyou Mountains (Klamath, Jackson, and Josephine Counties) the forest is different from that in the drier parts of the State. In these two ranges the yellow pine is intimately mixed with sugar pine, Douglas fir, white fir, and incense cedar, and occurs in the largest proportion on southerly exposures. On the cooler, moister situations it gives way to heavy stands of Douglas fir. Here there is ordinarily a great deal of underbrush and chaparral, and the more open the woods the greater the amount of brush. In this region its usual mature size is larger than in the other parts of the State.

DISTRIBUTION OF AGE CLASSES.

Yellow pine grows commonly in many-aged stands; i. e., trees of all ages from seedlings to 500-year-old veterans, with every age gradation between, are found in intimate mixture. In some stands there is a preponderance of very old trees; in fact, in many of the virgin stands of central and eastern Oregon there are more of the very old trees and less of the younger than the ideal forest should contain. Usually two or three or more trees of a certain age are found in a small group by themselves, the reason being that a group of many young trees usually starts in the gap which a large one makes when it dies. In the virgin stands throughout the State there seems to be a very large proportion of trees whose age is about 225 or 275 years, suggesting that after this age their mortality is greater.

Table 5 shows the uneven age of an average yellow-pine stand. It is an enumeration of the trees of each age on a logged-over tract near Embody, Lake County, the rings on the stumps of practically all the sound merchantable trees being counted.

Table 5.—*Number of trees of each age by decades on a representative 40-acre tract near Embody, Oreg., only trees (cut in a clean-cutting logging operation) whose annual rings could be counted being taken.*

Age.	Number of trees.	Age.	Number of trees.	Age.	Number of trees.	Age.	Number of trees.
100	4	190	22	280	15	370	3
110	2	200	19	290	9	380	1
120	13	210	8	300	7	390	1
130	8	220	13	310	11	400	5
140	14	230	17	320	8	410	2
150	31	240	28	330	13	420	2
160	16	250	21	340	10	430	1
170	21	260	13	350	6	440	6
180	20	270	10	360	2	450	17

NUMBER OF TREES PER ACRE.

Table 6 shows the average space in square feet controlled by trees of various sizes in a representative stand of pure yellow pine in central Oregon.[1]

Table 6.—*Space available to average trees of various sizes in pure yellow-pine forests. Basis, 45 trees.*

[Data taken near Mill Creek, Crook County.]

Diameter class.	Space available to each tree.	Diameter class.	Space available to each tree.
Inches.	*Square feet.*	*Inches.*	*Square feet.*
16	1,031	26	1,022
18	944	28	1,307
20	1,122	30	1,405
22	1,225	32	1,366
24	1,235	34	1,947

By this table it is seen that each tree 16 inches in diameter occupies in the virgin forest 1,031 square feet, allowing thereby only a possible 42 trees per acre; if they averaged 30 inches in diameter and required 1,405 square feet, there would be space for but 31 trees. But there are usually so many gaps in the yellow-pine forest that there are considerably less than this possible theoretic number of trees. The difference between the yellow-pine and the Douglas-fir forests is striking. In forests of Douglas fir in western Oregon there are commonly as many as 167 trees per acre, when the diameter of the average tree is 16 inches, and 88 trees when the average is 26 inches.[1]

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[1] The area controlled by each tree is considered to be the irregular polygon about the tree whose corners are at half the distance to each neighboring tree's base.

In pure, fully stocked stands in the Blue Mountain region there are commonly from 20 to 30 yellow pines per acre over 12 inches in diameter, of which but few are over 30 inches. Over large areas the average number per acre is ordinarily less than 20. On the slopes of the Cascades the number of trees per acre averages somewhat less than in the Blue Mountains, but the trees are larger. In mixed stands the number of yellow pines of merchantable size is naturally less, though the total number of trees of all species is as a rule larger, the moist soil on which the mixed forest grows being able to carry a denser stand.

Table 7 gives an indication of the average number of trees per acre and the distribution of their diameter classes in representative stands in various parts of the State; it is based on the measurement of several large sample plots in each locality. It does not attempt to show the comparative density or size of the timber or the mixture of species in the several regions, but merely shows by samples the variability of Oregon's normally stocked virgin forests.

TABLE 7.—*Number of trees per acre by diameter classes of yellow pine and of other species in several representative stands in central and eastern Oregon.*

Diameter at breastheight.	Near Austin and Whitney, Grant and Baker Counties. Basis: 258½ acres.		Near Lookingglass Creek, Union County. Basis: 44 acres.		Near Winlock's Mill, Wheeler County. Basis: 20 acres.
	Yellow pine.	Others.	Yellow pine.	Others.	Yellow pine.
Inches.					
2	3.70	4.30	4.00	4.00	....
4	2.46	3.44	3.00	3.00	11.45
6	2.22	2.58	3.11	3.55	11.45
8	2.29	1.41	5.02	1.41	4.50
10	1.90	1.04	5.11	1.39	2.55
12	2.01	.94	5.27	1.09	2.85
14	2.23	.86	4.53	1.07	2.80
16	2.21	.59	3.43	.59	1.70
18	2.54	.69	3.34	.45	1.35
20	2.65	.53	2.52	.57	1.40
22	2.50	.53	2.86	.48	1.50
24	2.45	.41	2.75	.29	1.65
26	2.26	.32	2.68	.32	1.25
28	1.99	.22	2.07	.09	.95
30	1.41	.20	1.41	.09	.55
32	1.15	.14	1.21	.07	.25
34	.80	.06	.68	.09	.30
36	.52	.08	.80	.11	.10
38	.37	.07	.25	.09	....
40	.16	.01	.36	....	....
42	.08	.02	.14	....	....
Over 43	.09	.03	.27	....	....
Total	38.00	18.47	54.81	18.75	46.60
Total over 12 inches	25.42	5.70	34.57	5.40	16.65

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[1] Forest Service Circular 175, "Growth and Management of Douglas Fir in the Pacific Northwest," by Thornton T. Munger.

TABLE 7.—*Number of trees per acre by diameter classes of yellow pine and of other species in several representative stands in central and eastern Oregon*—Continued.

Diameter at breastheight.	Near Embody, Lake County. Basis: 30 acres.		Near Lapine, Crook County. Basis: 40 acres.	Klamath Lake Region, Klamath County. Basis: 159 acres.	
	Yellow pine.	Others.	Yellow pine.	Yellow pine.	Others.
Inches.					
2	14.11	0.08	0.75	6.71	8.52
4	9.41	.07	.50	5.23	5.29
6	4.71	.05	.25	2.72	5.28
8	4.73	.13	.32	2.09	2.46
10	4.33	.17	.22	1.94	1.29
12	3.27	.06	.25	1.79	1.35
14	3.83	.06	.35	1.84	1.06
16	3.67		.25	1.99	1.21
18	3.30	.06	.42	2.09	.67
20	2.83		.65	2.35	1.14
22	2.80		1.00	1.96	.45
24	2.23	.03	1.10	2.27	.72
26	2.20		1.15	1.99	.62
28	1.70		1.22	2.46	.48
30	1.47		1.40	1.74	.45
32	1.33		1.32	1.35	.44
34	1.30		.67	1.10	.36
36	.80		.80	.72	.24
38	.37		.60	.59	.16
40	.20		.42	.38	.15
42	.30			.30	.08
Over 43	.40		.27	.45	.26
Total	69.29	.71	13.91	44.06	32.68
Total over 12 inches	32.00	.21	11.87	25.37	9.84

VOLUME PER ACRE.

Yellow-pine forests are so irregular in density that figures for the average stand per acre or per quarter section are apt to be misleading. Though the volume of timber may be very high on an area of an acre or so, there are usually openings in the forest, groups of young growth, glades, or barren spots, which reduce the average per acre volume of any large tract. Single sample acres frequently have a stand of 50,000 feet b. m. both in the Blue Mountain region and on the Cascades, but it is considered to be a good quarter section that has 4,000,000 feet b. m. or 25,000 feet to the acre. The following estimates of the amount of merchantable timber on two small watersheds, in different parts of the State, are representative of the regions which they typify, and illustrate the average density and composition of species on large tracts such as are now being logged. Estimate A is for a watershed at the head of one branch of the John Day River in the Blue Mountains, and Estimate B is for a watershed on the eastern slopes of the Cascades in Klamath County.

Estimate A.

Total area of watershed	acres	11,777
Area covered by merchantable timber [1]	do	6,297
Average stand per acre, of all species, on area of merchantable timber	feet b. m.	13,672
Total stand composed of—		
Western yellow pine	per cent	84
Western larch	do	9
Douglas fir, white fir, and lodgepole pine	do	7

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[1] The balance of the watershed is meadow, barren "scabby" ridges, patches of young timber, and noncommercial stands of lodgepole pine.

Estimate B.

Total area of tract	acres	7,120
Area covered by merchantable timber [1]	do	6,503
Average stand per acre, of all species, on area of merchantable timber, feet b. m.		18,683
Total stand composed of—		
Western yellow pine	per cent	64
Douglas fir	do	21
White and Shasta firs	do	12
Sugar and white pine	do	2
Lodgepole pine, Engelmann spruce, and incense cedar	do	1

LOG GRADES.

Tracts of timberland in various parts of the State are very variable in the quantity of timber that they carry; and there is just as much variance in the quality. In cruising the timber on a tract for purposes of sale, it is customary to estimate the amount of the upper grades that the tract will yield. Good yellow-pine timberland will yield 50 per cent of "No. 2 Shop" lumber or better.

It would be desirable to have in general use a scheme for grading yellow-pine logs in the standing forest, similar to that used by the Forest Service in its cruises, or similar to that used in marketing rafts of Douglas-fir logs on the coast, so that the yield of a tract could be expressed in terms of the amount of No. 1, No. 2, and No. 3 logs, or clear, shop, and common logs. The specifications for such log grades proposed by the Forest Service and in use in Government cruises in Oregon are as follows:

No. 1 logs shall be 22 inches or over in diameter inside the bark at the small end and not less than 10 feet long. They shall be reasonably straight-grained, practically surface clear, and, in the judgment of the scaler, capable of cutting not less than 25 per cent of their scaled contents into lumber of the grades of C select and better (including Factory C).

No. 2 logs shall be 18 inches or over in diameter inside the bark at the small end, not less than 8 feet long, and, in the judgment of the scaler, capable of cutting not less than 30 per cent of their scaled contents into lumber of the grades of No. 2 shop and better (including No. 1 common).

No. 3 logs shall be 6 inches or over in diameter inside the bark at the small end and not less than 8 feet long, having defects which, in the judgment of the scaler, prevent their classification into either of the above two grades.

Two mill-scale studies have recently been made in the Blue Mountain region to determine the amount of each grade of lumber obtainable from logs of each of the grades above described. One of the studies (labeled Test A) was made where the quality of the timber was exceptionally good and the other (labeled Test B) was made where it was poorer than the usual run. The results of both studies are presented in Table 8;[2] the average run of Blue Mountain yellow-pine timber would probably fall between the two extremes.

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[1] The balance of the watershed is meadow, barren "scabby" ridges, patches of young timber, and noncommercial stands of lodgepole pine.

[2] From manuscript reports by Forest Examiner H. B. Oakleaf, dated November, 1913, and March, 1915.

TABLE 8.—*Quality of sound yellow-pine logs*[1] *in the Blue Mountain region of Oregon.*

Lumber grades.	Test A, good quality timber, log grades.				Test B, poor quality timber, log grades.			
	1	2	3	All.	1	2	3	All.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
B and better	18.8	3.0	0.2	8.1	17.4	4.3	1.5	3.7
C select	17.4	5.9	1.2	8.9	15.8	6.4	2.9	5.3
D select	8.0	3.8	2.5	5.0	8.4	5.5	4.3	5.1
No. 1 shop	13.6	15.9	4.2	11.8	10.8	12.1	2.6	7.2
No. 2 shop	14.3	28.5	14.8	19.3	14.6	21.4	10.3	15.3
No. 3 shop	7.2	9.8	12.6	9.6	4.9	5.9	5.3	5.6
No. 1 common	.8	2.8	4.5	2.5	2.2	6.9	18.6	12.5
No. 2 common	4.7	13.8	22.9	12.9	8.6	13.0	25.0	18.7
No. 3 common	10.9	13.8	31.0	17.6	14.4	20.1	23.9	21.7
No. 4 common	4.3	2.7	6.1	4.3	2.9	4.4	5.6	4.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Per cent of each log grade	39	35	26	100	8	44	48	100

[1] Green lumber. Depreciation in drying not provided for.

GROWTH.[1]

INDIVIDUAL TREES.

Because of the wide range of conditions under which it grows the rate of growth of yellow pine is exceedingly variable, perhaps rather more so than that of most species. In very favorable situations it grows so much each year that it would be classed as a rapid-growing species; in unfavorable situations it is exceedingly slow. In eastern and central Oregon its average rate of growth is somewhat more than in the southern Rocky Mountain region and the southwest, and decidedly more than in the Black Hills of Dakota.[2] The upper slopes of the Sierras in California is the region of most rapid growth. The growth there is probably about the same as on the Siskiyou Mountains and the west slope of the Cascade Mountains, the region of most rapid growth in Oregon. For the Siskiyou and Cascade regions, however, no specific growth data are available.

Broadly speaking, during its first 10 or 15 years yellow pine grows very slowly; then follows a period of 75 or 100 years in which both diameter and height growth are rapid, exceptionally thrifty trees making an increase of one-half inch in diameter and 2 feet in height in one year. By its one hundred and fiftieth year the height increment has fallen off very much, the tree has nearly reached its mature height, and thereafter grows but a foot or two each decade. Diameter growth also decreases after the first century of life, the rings become narrower and narrower with age, and on very old trees, or those that have been suppressed, they are so fine as to be hardly distinguishable except with a magnifying glass. It is usual, therefore, for the annual rings to be broad and well defined in young trees and at the center of old ones, but narrow in the exterior rims of old trees, sometimes 90 to an inch of radius.

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[1] The tables and some of the other material in this chapter are taken from the manuscript report prepared by Mr. G. A. Bright, forest assistant, entitled "A Study of the Growth of Yellow Pine in Oregon," which embodies in detail the results of the field study of this species made by the Forest Service in 1910–11.

[2] Forest Service Circular 127, "Forest Tables—Western Yellow Pine."

Yellow pine is a long-lived tree. The oldest encountered in the analysis of 4,997 stumps in eastern and central Oregon was in its six hundred and eighty-seventh year when cut for lumber.

DIAMETER AND HEIGHT GROWTH.

In Tables 9 and 10 the rate of growth of yellow pine, both in height and diameter, is given for a number of typical localities in the central and eastern parts of the State. These measurements are the result of detailed study and analysis by the Forest Service of 4,997 felled trees[1] in 20 different localities. The wide variation in the rate of growth in the several regions should not be interpreted to indicate necessarily the superiority of one region over another, but rather the effect of local variations in soil, exposure, or climate upon the rate of growth. In some regions of the State the data were taken in very favorable, well-watered situations, while in other regions it chanced that the data were collected in unfavorable situations.[2]

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[1] In 1910 and 1911.

[2] In order that the growth in these several localities may be compared intelligently, the following brief description of the conditions on each is given:

1. Austin, Whitney, Grant, and Baker Counties: Practically pure stands on rather dry, rolling hills at altitudes of from 4,500 to 4,800 feet. Soil: Loamy, decomposed lava, not deep.

2. Lookingglass Creek, Union County: Stands with about 5 per cent of other species, growing in coves and on gentle slopes at an altitude of 3,200 feet. Climate: More humid than is usual at that elevation in the Blue Mountains. Soil: Good, deep, loamy, decomposed lava.

3. Parker's Mill, Morrow County: Pure yellow-pine stand near foot of gentle south slope. Altitude: 3,500 feet. Soil: Fairly deep, loamy, decomposed lava.

4. Winlock's Mill, Wheeler County: Pure yellow-pine stand on hot, dry, south slope. Altitude: About 3,300 feet. Soil: Fairly deep, loamy, decomposed lava, very dry in summer.

5. Ochoco Creek, Crook County: Pure yellow-pine stand on all slopes of rolling country, near lower altitudinal limits of forest. Altitude: About 3,000 feet. Soil: Loamy, decomposed lava, very dry in summer

6. Mill Creek, Crook County: Stands with 10 per cent or so of other species on a rolling plateau at altitude of 3,500 feet. Soil: Loamy, decomposed lava of good depth, not excessively dry.

7. Tamarack Creek, Wasco County: Stands averaging at least 10 per cent of other species, growing on steep slopes on both sides of the creek. The soil is loamy and the moisture conditions better than average

8. Metolius Creek, Crook County: Stands with about 5 per cent of other species on fairly level ground: where moisture conditions are good (for east of the Cascades) and the soil deep and loamy.

9. Sisters (1), Crook County: Pure stand of yellow pine on flat at altitude of about 3,000 feet. Soil: A loose, gravelly sand, nonretentive of moisture. Sisters (2) tract is very similar in every respect to the Sisters (1) tract.

10. Bend, Crook County: Pure stand of yellow pine on south slopes closely adjoining treeless desert at altitude of 3,700 feet. The soil is shallow and sandy.

11. Lapine (1) and (2), Crook County: Almost pure stands on a flat at altitude of about 4,200 feet. Soil a loose, sterile, coarse pumice, nonretentive of moisture. The location and physical condition on (1) and (2) are very similar.

12. Lapine (3), Crook County: Same as Lapine (1) and (2) except located on a lower bench, 15 feet above Deschutes River, so that it, doubtless, receives some helpful subirrigation.

13. Fort Klamath, Klamath County: Stands composed of 25 or 30 per cent of other species on flat at altitude of 4,100 feet. Soil: A fine, loose pumice. Climatically, moisture conditions are good.

14. Crystal Creek, Klamath County: Stand with about 30 per cent of other species on east slope at altitude of 4,200 feet. Soil: Rocky, loamy, decomposed lava. Moisture conditions are good.

15. Odessa, Klamath County: Stand averaging 85 per cent yellow pine on benches and gentle east slope. Altitude: About 4,200 feet. Soil: rocky, loamy, decomposed lava.

16. Meadow Lake, Klamath County: Stand about 90 per cent yellow pine on rolling hills at altitude of 4,500 feet. Soil: Loamy, decomposed lava, probably with some lime content.

17. Keno, Klamath County: Practically pure stand on low rolling hills at altitude of 4,200 feet. Soil: Loamy, decomposed lava; site rather dry in summer.

18. Embody, Lake County: Stand practically pure yellow pine on easterly slope at altitude of 5,000 feet. Climate: Rather dry and severe. Soil: Loamy, decomposed lava.

From these tables it is possible to determine what height and what diameter a yellow pine may be expected to reach in 50, 100, or 150 years under each of the several sets of conditions which each locality typifies. These data were of course collected in virgin forests. A comparison of the growth of the present young trees with the growth of the old trees when they were young, and of the growth of trees of various sizes, indicates that the young, thrifty trees now are growing at the same rate that their parent trees did when they were of the same age. It is fair to assume, therefore, that future growth in the natural forest will be at the same rate.

Table 9.—*Average total height of yellow-pine trees at various ages for 13 typical stands in several localities in Oregon.*

Locality.	Basis: Number of trees.	Age of trees in years.							
		50	100	150	200	250	300	350	400
		Total height in feet.							
Austin and Whitney, Grant and Baker Counties	437	22	58	86	100	110	115	117	119
Lookingglass Creek, Union County	588	38	79	104	115	119	121	122	123
Ochoco Creek, Crook County	187	19	54	79	93	101	104	106	107
Mill Creek, Crook County	224	29	66	88	107	118	124	126	129
Tamarack Creek, Wasco County	125	23	70	95	106	108	109	109	109
Metolius Creek, Crook County	36	25	65	95	113	124	129	130	130
Sisters, Crook County (1) and (2)	128	22	59	79	88	91	92	93	93
Bend, Crook County	66	21	54	82	90	91	92	......	......
Lapine, Crook County (1) and (2)	131	14	48	81	99	111	117	121	122
Lapine, Crook County (3)	57	24	64	90	105	116	122	125	126
Fort Klamath, Odessa, Meadow Lake, and Keno, Klamath County	460	29	69	92	106	114	118	121	124
Crystal Creek, Klamath County	86	23	65	120	139	146	149	150	150
Embody, Lake County	22	22	59	80	91	97	103	108	113
Total	2,547	......	......	......	......	......	......	......	......
Average	......	24	62	90	104	111	115	119	120

Table 10.—*Average diameters of yellow-pine trees at various ages for 18 typical stands in several localities in Oregon.*

Locality.	Basis: Number of trees.	Age of trees in years.							
		50	100	150	200	250	300	350	400
		Diameter in inches outside bark at breastheight.							
Austin and Whitney, Grant and Baker Counties	672	4.0	10.8	15.7	19.4	22.2	24.4	26.5	28.4
Lookingglass Creek, Union County	409	6.6	14.1	19.4	22.7	25.5	29.0	32.7	34.1
Parker's Mill, Morrow County	245	3.0	10.2	15.8	20.2	24.2	27.8	30.8	33.4
Winlock's Mill, Wheeler County	407	2.5	9.9	15.2	19.0	22.7	26.4	30.0	33.0
Ochoco Creek, Crook County	474	4.4	12.3	18.2	22.1	25.2	27.8	29.7	30.7
Mill Creek, Crook County	405	4.1	11.6	17.6	22.0	25.6	28.4	30.6	32.4
Tamarack Creek, Wasco County	238	5.0	14.6	20.5	24.0	26.2	28.1	29.7	31.0
Metolius Creek, Crook County	66	4.4	13.1	19.1	23.6	27.1	30.0	32.2	33.8
Sisters, Crook County (1)	267	3.9	12.8	18.6	22.7	25.8	28.8	31.3	33.6
Bend, Crook County	183	4.7	15.4	20.7	24.4	27.3	29.9	......	......
Lapine, Crook County (1)	361	2.8	9.6	17.9	23.2	27.4	30.6	33.2	35.5
Lapine, Crook County (3)	91	3.4	11.5	20.2	26.0	29.9	32.8	35.1	36.7
Fort Klamath, Klamath County	110	5.9	17.1	24.3	28.2	31.2	33.8	36.3	38.5
Crystal Creek, Klamath County	87	10.6	22.2	28.5	33.1	37.0	40.7	......	......
Odessa, Klamath County	156	4.5	13.9	20.0	23.8	26.5	28.8	30.9	33.0
Meadow Lake, Klamath County	245	5.0	13.3	19.3	23.3	26.5	28.8	30.7	32.5
Keno, Klamath County	52	5.7	14.0	20.0	23.5	26.1	28.3	30.1	31.7
Embody, Lake County	400	3.5	10.5	16.1	20.1	23.1	25.5	27.8	29.9
Total	4,868	......	......	......	......	......	......	......	......
Average	......	4.7	13.2	19.3	23.4	26.6	29.4	31.1	30.0

An analysis of these tables brings out some interesting points. Rapid diameter and rapid height growth are by no means associated always; a stand may make a very good diameter growth and yet poor height development, particularly in some of the open stands in the dry situations bordering the desert. Sustained growth rate seems also to depend upon the character of the situation. Apparently the rate is sustained longest on the poor sites where it is the lowest, as though the tree were striving to reach certain dimensions before its increment slackened.

The period of most rapid growth is reached early in the life of the tree. In all the 18 localities for which data are given above, the culmination of the annual growth in diameter takes place between the fortieth and the one hundred and fiftieth year, usually about the seventy-fifth year; in height growth, it takes place between the forty-third and ninety-seventh years, averaging about the sixty-fifth year. The culmination of the mean annual growth is of course later, and in these localities was found to be between the seventy-eighth and the one hundred and forty-fifth year (average 109 years) in the case of height growth, and between 80 and 190 years (average 120 years) in the case of diameter growth. While the data are not wholly consistent, both the mean and the annual diameter and height growth culminate latest on the poorest sites.

VOLUME GROWTH.

No specific volume growth measurements were taken in the field, but the volume growth tables have been derived from volume tables and the diameter and height growth data.

Table 11 indicates the average number of board feet in trees of various ages in several typical localities. It shows that in an unfavorable site, such as that near Winlocks Mill, the trees do not come to be of merchantable size (12 inches in diameter) until 140 years old, and that it takes 200 years for a tree to have a volume of 280 board feet, and 300 years for it to have 900 feet; while on a favorable site, such as at Fort Klamath, the average tree becomes merchantable in 80 years, and at 200 years contains 1,190 board feet. The culmination of the annual and mean annual volume growth takes place, as would be expected, later than that of the diameter and height growth. The period of most rapid current volume growth (which may be derived from Table 11) falls variously from the one hundred and fiftieth year to the limit of the table, while the maximum mean annual volume growth usually occurs outside the limits of the table, 500 years.

TABLE 11.—*Average merchantable volume in board feet of yellow-pine trees at various ages for 10 typical localities in Oregon.*

Age, years.	Whitney and Austin.	Looking-glass Creek.	Winlock's Mill.	Ochoco Creek.	Sisters (1).	Lapine (1).	Fort Klamath.	Odessa.	Meadow Lake.	Embody.	Average.[1]
	Volume of tree, in board feet.										
20	....	....	....	....	....	....	....	....	....	....	....
40	....	....	....	....	....	....	....	....	....	....	....
60	....	....	....	....	....	....	....	....	20	....	55
80	....	....	....	....	....	....	80	20	50	....	92
100	50	150	....	....	20	....	230	90	95	....	140
120	150	260	20	70	105	....	400	180	160	10	172
140	205	380	75	165	195	80	600	300	250	115	279
160	275	500	140	265	290	210	800	440	360	180	407
180	350	605	205	375	390	370	1,000	580	490	250	544
200	430	705	280	480	500	540	1,190	710	630	320	688
220	510	810	365	600	610	730	1,370	830	780	400	835
240	590	935	470	720	730	920	1,550	950	920	480	982
260	670	1,070	590	840	860	1,110	1,730	1,060	1,050	570	1,130
280	750	1,230	740	960	980	1,300	1,910	1,170	1,170	670	1,279
300	835	1,430	900	1,070	1,110	1,480	2,090	1,280	1,290	770	1,430
320	925	....	1,090	1,170	1,240	1,660	2,260	1,380	1,400	880	1,431
340	1,020	....	1,270	1,260	1,370	1,820	2,430	1,480	1,510	990	1,564
360	1,110	....	....	1,320	1,500	1,980	2,600	1,580	1,610	1,110	1,702
380	1,210	....	....	1,370	1,600	2,120	2,770	1,680	1,700	1,230	1,838
400	1,300	....	....	1,420	1,790	2,260	2,940	1,770	1,790	1,340	1,955
420	1,390	....	....	1,450	1,930	2,400	....	....	1,870	1,440	2,017
440	1,480	....	....	1,470	2,070	2,540	....	....	1,940	1,540	2,123
460	1,570	....	....	1,490	2,210	2,680	....	....	2,010	1,640	2,155
480	1,660	....	....	1,500	2,350	2,820	....	....	2,080	1,730	2,240
500	1,750	....	....	1,510	2,490	2,960	....	....	2,150	1,820	2,322

[1] The average of 20 separate stands in Oregon, the data for only 10 of which are given in the above table.

FACTORS AFFECTING GROWTH.

The most important single factor that affects growth is the amount of available soil moisture. Provided that climate and drainage are satisfactory, the most rapid growth is found in well-watered situations—in coves, on moist north and south slopes, and on benches. Heat also tends to promote the vigor of growth, provided soil and moisture conditions are satisfactory; hence at the higher, colder elevations and in cold situations growth is slower.

Another factor which materially affects the rate of growth of individual trees is the density of the stand. In the study of the crown space needed by trees of various sizes (see Table 6) it was found that trees make their maximum growth when they have more space than they do in the average virgin forest, open as it is. Beyond a certain point increase in available crown space apparently does not cause an increase in the growth rate. In some situations an excess of room seems to inhibit growth, perhaps because it subjects the tree to excessive exposure to wind and evaporation. It is natural to expect that selection cuttings such as are practiced on the National Forests (described in the chapter on "Management") will stimulate the reserved trees to more rapid growth, and such is found to be the case.

In a detailed study[1] of several areas in the Blue Mountains, partially logged over several years ago, the increase in the basal area growth of the reserved trees was found to be very large. On seven sample plots which were studied intensively it amounted to 310, 219, 242, 141, 103, 63, and 48 per cent, respectively. On these areas the increase in the growth rate was in inverse relation to the volume of the reserved trees on the sample plot. Where there were many trees left standing there was less stimulation than where there were few. The acceleration in growth was also more noticeable where the reserved trees were evenly distributed than where they were crowded into groups.

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[1] Manuscript report by R. H. Weitknecht, assistant forest ranger.

The measurement of a similar area in Klamath County lightly culled over some 24 years ago, on which "bull pines" and somewhat misshapen older trees were left, showed the increase in the growth of these reserved trees to have been surprisingly large since the thinning was made, amounting in one sample plot[1] to 105 per cent in the volume growth, and in another[2] to 63 per cent in the basal area growth.

Yellow pine's rate of growth responds quickly to changes in the soil moisture, soil depth, aspect, climate, density of the stand, etc.; and the changes in these factors are very frequent in the mountainous country such as yellow pine inhabits. Within the Blue Mountain region alone, on neighboring tracts (Winlock's Mill and Mill Creek) both of which support typical commercial yellow-pine stands, the volume growth of a 190-year-old tree is in the one case 3.7 board feet per year, and in the other 9.0, a range of 240 per cent.

STANDS.

It is easy to determine the rate of growth of individual trees, but extremely difficult to find out, even approximately, that of stands, especially when only uneven aged and virgin forests which are irregular in density are available for measurement. Theoretically, and actually on large areas, there is no net growth in the virgin forest; i. e., the growth of the living trees is just offset by the death of occasional old ones. Young trees take the place of the dying ones just rapidly enough to preserve indefinitely a uniform volume. Assuming that no trees died, the growth on an acre in such stands as those listed in Table 7 would probably be 100 board feet or more per year on average soils, and fully 200 feet on good soils.[3]

The forester, however, is particularly interested in the rate of growth that he can secure on lands that have been cut over under proper regulations. Until there is an opportunity to remeasure sample plots in areas which have been cut over, exact yield data of this character will be lacking. Estimates based upon the gross growth of virgin forests, which take into consideration the several unmeasurable factors—lessened number of trees per acre after cutting, occasional loss of some trees on account of accidents, increased growth after cutting due to more growing space—point to the conclusion that central and eastern Oregon yellow-pine timberland can be counted upon to yield annually for an indefinite time from 75 board feet per acre on poor sites to 175 board feet on good sites. This is not large when compared with the 800 or 1,000 board feet per acre per year yields of the best Douglas-fir forests west of the Cascades; but the climate in the yellow-pine belt is such that the productivity of the forest soil is inevitably not large.

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[1] Manuscript report, "Silvicultural Aspects of Cutting in Open Yellow-Pine Forests," by H. D. Foster, forest assistant.

[2] Manuscript report, "Notes Regarding Increased Growth in Yellow-Pine Stands as the Result of a Selection Cutting," by Thornton T. Munger, forest assistant.

[3] Growth rate of individual trees as shown in Table 11.

CHARACTERISTICS OF THE WOOD.

Botanically western yellow pine belongs to the subfamily of the hard or "yellow" pines rather than to that of the soft or "white" pines. In characteristics the wood is midway between the two. It is described as follows:[1]

> Rather light, not strong, grain fine, even, often twisted; annual rings variable in width, summerwood broad or narrow, resinous; resin passages medium and rather numerous; medullary rays not numerous, prominent; color very light yellow to reddish, thick sapwood almost white; not durable in untreated condition, but readily receives treatment.

The smaller trees, i. e., the so-called "bull pines," and the centers of the larger trees have a coarse-grained wood, in which the annual rings are prominent and the summerwood rather hard, resembling that of some of the southern yellow pines. The outside of the larger trees, particularly of the slower-growing ones, is soft, uniform-textured, and resembles strongly the wood of the eastern white pine, western white pine (Idaho white pine), and sugar pine. The wood from the outside of the lower logs of old trees is apt to be fairly clear of knots, the worst defect in this lumber; but that from the upper part of the tree and from young trees is almost always knotty, even though the outside of the log may appear fairly smooth. Much of the yellow-pine timber cut in Oregon is so soft and white that it is shipped east and used with satisfaction for purposes for which real white pines and sugar pine have been used previously. The character of the wood varies with the situation, a fact well known to lumbermen, who find that the timber in certain localities produces a larger percentage of the high-grade soft "shop" lumber than that in other localities where it is similar in exterior appearance.

The following statistics summarize the characteristics of the wood.[2]

> Average weight of oven-dry wood, 26.5 pounds per cubic foot. (Sargent.) (Exceptionally soft, light specimens from central Oregon weighed, air dry, 22 pounds per cubic foot.)

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[1] Forest Service Bulletin 99, "Uses of Commercial Woods of the United States; II, Pines."

[2] For further description of the wood, see Forest Service Bulletin 101, "Western Yellow Pine in Arizona and New Mexico," by T. S. Woolsey, p. 33.

Specific gravity (dry), 0.42.

Fuel value, 63 per cent of that of white oak. (Sargent).

Average breaking strength (modulus of rupture) of small clear pieces, green 5,659, air dry 10,871 pounds per square inch, or 70 per cent that of green Douglas fir.

Average factor of stiffness (modulus of elasticity) of small clear pieces, green 1,159,000, air dry 1,534,000 pounds per square inch, or 65 per cent that of green Douglas fir.

Length of fiber, from 2.5 mm. to 3.3 mm.

Weight of 1,000 feet b. m. of green logs (assorted sizes from Blue Mountains, Oreg.), from 7,000 to 8,000 pounds.

Weight of 1,000 feet b. m. of rough green lumber, from 3,500 to 3,700 pounds.

Shipping weight of 1,000 feet b. m. of 1-inch rough air-dry lumber, 2,400 pounds.

UTILIZATION OF YELLOW-PINE FORESTS.

LUMBER.

The major product of yellow-pine forests is lumber in its various forms. Oregon's yellow pine has been cut for local use by small mills since the first settlement of the country some 60 years ago, but until the last 10 years relatively little extensive lumbering has been carried on. The yellow-pine cut-over lands therefore are chiefly in small patches adjoining small mills, and only in a few places, chiefly along the main line of the Oregon Washington Railroad and Navigation Co. and its tributary lines in the Blue Mountains, are there extensive stump lands.

Western yellow-pine lumber is used for almost every purpose to which any pine lumber is put. Through central and eastern Oregon, and in fact throughout most of its range, western yellow pine is the most abundant timber tree, and is superior to most of its associates for the large variety of purposes for which it is used. Many houses in Oregon are built entirely of yellow pine, even the shingles, floors, and trimmings. Besides what is used within the State for buildings, railroad structures, fencing, and construction purposes, Oregon exports a large amount of the better grades each year. That shipped from eastern Oregon goes largely to the timberless parts of the Rocky Mountain States, to the Middle West, and even to the East, where it is used as a general all-purpose factory material for the manufacture of doors, sash, finish, shelving, moldings, and special factory products, pattern material, bevel and drop siding, rustic ceiling, and flooring. Some of that shipped from southern Oregon goes to California and Nevada. Much of the lower-grade material is manufactured into boxes in the State, and large quantities go to California for fruit boxes.

FUEL, POSTS, ETC.

Yellow pine makes excellent fuel, for which both the green and the dead timber are used. In addition to being sawed for lumber and used for fuel, a very little is used in the State in the round for house logs and frames, fence rails, and posts, but for these purposes it is inferior to its associates, western larch, Douglas fir, and lodgepole pine. It is only the "pitchy" parts of the tree that are durable in the ground and are prized for posts.

PULP.

Western yellow-pine wood has never been used commercially for paper. Experiments made with it at the Forest Products Laboratory of the Forest Service indicate that it has decided possibilities for this purpose. With the soda process it yielded per cord 1,470 pounds of pulp, the fiber of which was strong and of brown color, and which would probably make a good grade of wrapping paper. By the mechanical process it yielded 2,290 pounds of pulp, which had long fibers and was creamy in color, but coarse and suitable only for making manila and other papers where color and coarseness are of no importance.

STOCK GRAZING.

One minor use, grazing of stock, and a suggested use, the extraction of naval stores, deserve especial mention in considering the utilization of yellow-pine forests.

In the yellow-pine forests of Oregon (except those on both slopes of the Cascades south of Crater Lake and those on the Siskiyou Mountains in southern Oregon and on some of the pumice-stone land toward the head of the Deschutes River) the trees are so open-grown and the woods are so free of underbrush that a good herbaceous vegetation suitable for forage springs up each year. The character of the vegetation depends upon the region, but it usually consists in part of a variety of grasses and in part of "weeds" (annual flowering plants). In the Blue Mountains the herbage is rather more luxuriant and varied than on the eastern slopes of the Cascades and their outstanding ranges. In the early summer the open yellow-pine forests of the former region are as green with fresh herbage as a lawn, except here and there where the green is tinged with patches of yellow or purple flowers. Some of this luxuriant herbage is pine grass (*Calamagrostis* sp.), a plant which is not eaten by stock except very early in the season; but much of the ground cover makes excellent range for cattle and sheep. Nearly all the yellow-pine land in the State which is not too brushy or too sandy is grazed by one or the other of these classes of stock. It is thought that 3 acres will support a grown sheep (or a ewe and lamb) during the summer season, and 15 acres will support a cow. This makes the forage worth annually 5 or 10 cents an acre, which is a very decided additional revenue for the owners of forest land.

TURPENTINING.

In several particulars western yellow pine is similar to longleaf pine (*Pinus palustris*) of the South Atlantic and Gulf States, which is so valuable as a source of naval stores—turpentine and rosin.

Recent experiments in turpentining western yellow pine in Arizona and California [1] show that its yield of turpentine and rosin is very similar to that of the southeastern pines, comparing very favorably with that from longleaf pine (*Pinus palustris*). Although the season of flow was four or five weeks shorter in Arizona than in Florida, the yield of "gum" was about four-fifths as large for equal periods.

So far as is known, yellow pine has never been tapped for turpentine on a commercial scale in Oregon. In the summers of 1912 and 1913 experiments were undertaken by the Forest Service in Grant County to determine whether yellow pine in this locality would yield enough crude gum by the usual methods of tapping and whether its gum was of good enough quality to be of commercial value. The results obtained were not encouraging.[2] In 1912, 199 cups were hung on 108 trees and they yielded in a 21-week season 0.111 pound of gum per cup per week. In 1913, 201 cups were hung on 101 trees and they yielded in a 21-week season only 0.069 pound per cup per week. On the basis of 31-week seasons this is only 39 and 28 per cent, respectively, of the average Florida yield from longleaf pine. While the resin flowed throughout the season and was of good quality, the yield was so small as not to be commercially profitable under present conditions. The indications are that the nights are too cold and the warm season too short to allow of an abundant flow. It is the conclusion that under present economic conditions in the naval-stores industry turpentining of yellow pines in Oregon on a commercial scale is impracticable. With the exhaustion of the supply of more easily tapped trees elsewhere turpentining of yellow pine may become profitable. If so, it would undoubtedly have a marked influence upon the handling of timberlands and be an added source of revenue to their owners.

LOGGING AND MILLING.

METHODS OF LOGGING.

Yellow-pine logging is ordinarily done with horses, various methods being used according to the density of the timber, the topography, and the length of the haul.

The timber is felled with the saw (Pl. V), and bucked into from 12 to 20 foot, usually 16-foot, log lengths, sometimes the same crew doing the felling and the bucking, and sometimes the latter operation being done by special buckers working singly. The smooth, straight trees are utilized to a top diameter inside the bark of 6 or 8 inches, occasionally to an even lower limit; large trees with heavy branches or a crooked main stem are often not usable below 16 inches. Yellow

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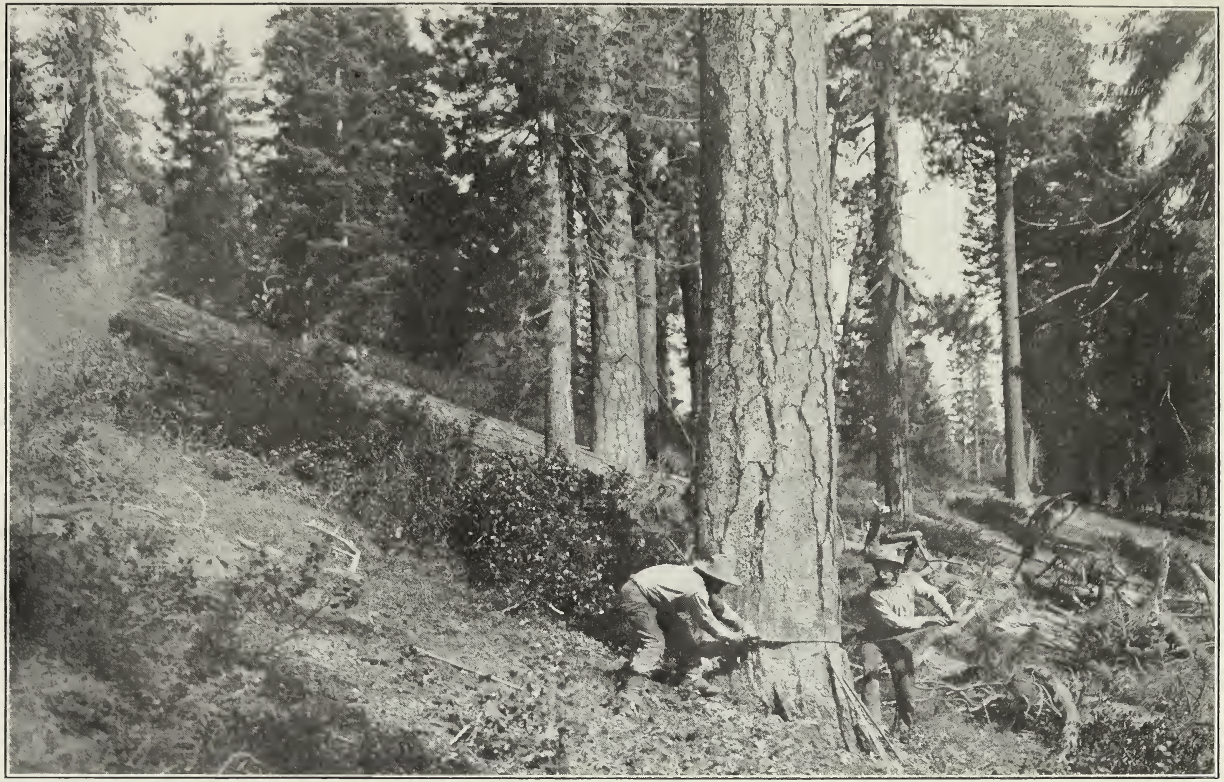
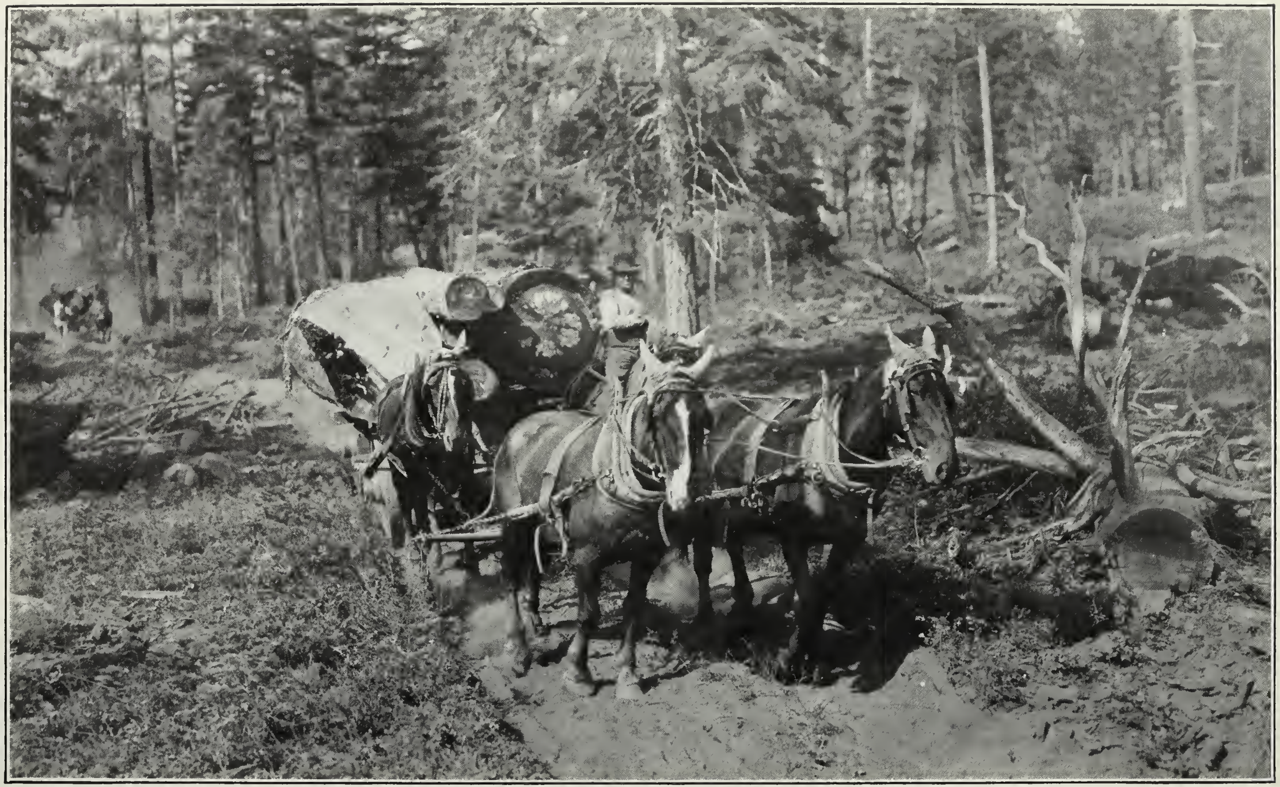
[1] Forest Service Bulletin 116, "Possibilities of Western Pines as a Source of Naval Stores," by H. S. Betts.

[2] Manuscript reports of J. B. Knapp, assistant district forester, "Turpentining Western Yellow Pine in Oregon," and of H. B. Oakleaf, forest examiner, "Turpentining Experiments on Western Yellow Pine Conducted on the Whitman National Forest."



FELLING A LARGE WESTERN YELLOW PINE IN KLAMATH COUNTY, OREG.

Showing the mixed forest of yellow pine, sugar pine, and white fir, and brushy ground cover which is characteristic of this region.



HAULING A LOAD OF LOGS FROM WOODS TO LANDING ON FOUR-WHEELED WAGON, KLAMATH COUNTY, OREG.

In background is a mixed yellow pine forest which has been cut over under the selection system.

pine falls heavily in open woods and is rather brittle, so that the breakage is bad unless the ground is smooth and care is taken by the felling crew to prevent crossing. The felling and bucking are done very commonly by contract, 70 cents per tree being now (1915) the usual price for these operations.

Usually the logs are first "bunched" or "skidded" with a team of horses and a pair of tongs, or with a team and a spool cart or a sled "go-devil," these methods being used for distances less than one-eighth of a mile except on a downhill pull, where they may be practicable for a quarter-mile haul. In case the distance is short the logs are brought directly to the railroad "landings" by one of these methods. Otherwise they are transported from the "bunches" to the mill or pond, or to the railroad, on four-wheeled trucks, or with "high" wheels. (See Pl. VI.) In practically every large yellow-pine operation in the State logging railroads are being used for carrying the logs from the points that can be reached economically by horses to their final destination at the mill. In some small operations the logs are hauled on trucks 2 miles or so, but where railroads are used the spurs are usually constructed so frequently that a haul with horses of over one-quarter mile will not be necessary for any considerable body of timber. In a few operations, where railroad construction is not feasible, a traction engine is being used to haul great wagonloads of logs for considerable distances along country roads from the woods to the mill.

Most of the yellow-pine timber in Oregon which is now being exploited and in which logging is likely to be carried on in the next few years is ideal for horse and railroad logging. The timber is of a size convenient for handling, the topography is ordinarily not too rugged nor the ground too rough, and the forest is open and fairly free of underbrush, so that little swamping is necessary. The climate and snow conditions are such that horse logging may be conducted nearly throughout the year in most parts of the yellow-pine region, though fewer operations are in progress during the winter. In a few instances logging yellow pine with steam skidders or with steam donkeys has been tried, but these methods have in some instances been unprofitable and do not seem to be coming into general use except on ground too steep for horses. In certain kinds of topography steam donkey logging is practicable where horse logging would be out of the question. River driving of yellow pine is practically not done at all in this State, and probably never will be to any large extent because of the scarcity of suitable streams. Klamath Lake is used as a waterway across which logs are towed from the woods to the mills.

The cost of logging yellow pine varies greatly with the local conditions—length of haul, lay of the ground, character and density of the timber, wage scale, efficiency of labor, etc. The following figures may be considered to represent the present average cost of an average operation in which 60,000 board feet are being taken each day from the standing timber and loaded on the log cars, using the ordinary methods of horse logging.

TABLE 12.—*Cost per thousand feet b. m. of logging yellow pine for an average sample operation.*

Operation.	Cost per 1,000 feet b. m.
Felling and bucking	$0.70
Brush piling and burning	.30
Hauling by horses, stump to landing	1.20
Loading	.20
Supervision	.10
Interest, depreciation, liability insurance, taxes, etc	.30
Total	2.80

MILLING.

There are all kinds of sawmills cutting yellow pine in Oregon, from the small portable mill that can cut not more than 6,000 feet of logs a day and runs only a few days a year to the large band mill that cuts 150,000 feet in 10 hours and runs day and night throughout the year. Altogether, there are in the State about 100 mills that cut yellow pine chiefly, and their aggregate daily capacity is a little under 2,000,000 feet, which would be equivalent to 600,000,000 feet per annum if every mill ran 300 days a year. Since many of them operate only a fraction of the time and cut other species of timber as well, the output in 1915 of the 134 mills that reported cutting some yellow pine was 189,203,000 feet, which was 15.1 per cent of the whole country's cut of this species. At the present time there are in Oregon less than 20 mills cutting chiefly yellow pine that have a 10-hour capacity of over 35,000 feet, and only 4 that have a capacity of 80,000 feet or more. Each year, however, new mills are being built.

Most of the smaller mills that cut for the local use of the community are equipped with a planer, upon which the better grades of boards are dressed for use as finishing lumber. The larger sawmills have elaborately equipped planing mills where the rough boards are kiln dried, resawed, surfaced, and dressed to such styles and sizes as will find the most ready sale in the eastern markets and bring prices that will repay the heavy transportation charges.

In the smaller mills the lumber is either sold "mill run" without grading or it is graded into "finishing lumber" (which is surfaced and sized), "common," and "cull" lumber. In the larger mills the lumber is carefully graded according to the specifications of the lumber associations.

LUMBER GRADES.

In Oregon two sets of grades are used, one in use through all the eastern part of the State, and the other in southern Oregon where the lumber is shipped to California. Table 13 shows the names of the principal grades and their average prevailing values f. o. b. mill or railroad during the past two years in two representative regions, the Blue Mountains and the Klamath Lake region. It should be remembered that the value of each grade is constantly changing and that the percentage of grade is very variable from tract to tract. The table is therefore an illustration, not a mathematical average:

TABLE 13.—*Average value of the various grades of lumber from two typical yellow-pine regions in Oregon.*

Blue Mountain region.		Klamath region.	
Name of grade.	Value per M feet.	Name of grade.	Value per M feet.
B select and better	$35 to $45	Nos. 1 and 2 clear	About $35.00
C select	30 to 37	No. 3 clear	About 30.00
D select	20 to 28	C select	About 30.00
No. 1 shop	25 to 28	No. 1 shop	About 24.00
No. 2 shop	16 to 19	No. 2 shop	About 17.00
No. 3 shop	11 to 14	Box	About 12.50
No. 1 common	21 to 24		
No. 2 common	14 to 18		
No. 3 common	11 to 14		
No. 4 common	8 to 10		

PLANTING.

Direct seeding with yellow pine in Oregon, either by sowing the seed broadcast or in prepared spots, does not promise good results so far as is indicated by the experiments already made. Better results will undoubtedly be secured by the planting of nursery-grown seedlings, though it will cost more initially. Since yellow pine produces such a long taproot, it is rather a difficult species to handle in the nursery and in field planting; therefore, plants older than 2 or 3 years, i. e., those about 6 inches tall, can not ordinarily be used profitably in forestation work. As yet, but little planting of yellow pine has been done in Oregon, and the experimental areas so far planted aggregate less than 100 acres; but the indications are that careful methods on reasonably appropriate sites will give satisfactory results. The average cost of establishing a forest plantation of yellow pine, 800 trees to the acre, is estimated as follows:

	Per acre.
Cost price of 2-year-old, once transplanted nursery trees, boxed for shipping	$3.50
Average cost of shipping stock to planting site and heeling it in	.50
Average cost of setting out the trees	5.00
Total cost	9.00

MANAGEMENT OF WESTERN YELLOW PINE FORESTS.

The economic conditions which affect the management of timberland held in public ownership are so different from those which control the management of privately owned lands that a separate discussion of each class is necessary. The administration of public forests, such as those held by the Federal and State Governments, is aimed to secure the greatest good to all concerned for all time; i. e., present-day financial returns are secondary to the larger considerations of sustained profit and public welfare. Privately owned forests must be so administered as to yield the greatest present-day profits, and this usually means harvesting the maximum yield within the lifetime of the individual owner. Table 14 shows the proportion of yellow-pine timberland in Oregon held under each class of ownership.

TABLE 14.—*Ownership of the yellow-pine forests of Oregon, 1913.*

Character of ownership.	Area.		Volume.	
	Acres.	Per cent.	Feet b. m.	Per cent.
In private ownership	4,448,026	44.4	34,812,400,000	48.6
In State ownership	16,332	.2	51,400,000	.1
In Federal ownership:[1]				
National forests	4,742,148	47.4	27,398,300,000	38.5
Indian reservations	800,000	8.0	9,100,000,000	12.8
Total	10,006,506	100.0	71,362,100,000	100.0

[1] To this might be added two or three hundred thousand acres in the public domain which carries four million feet of yellow pine, most of which is too scattered and of too inferior quality to be considered of commercial importance.

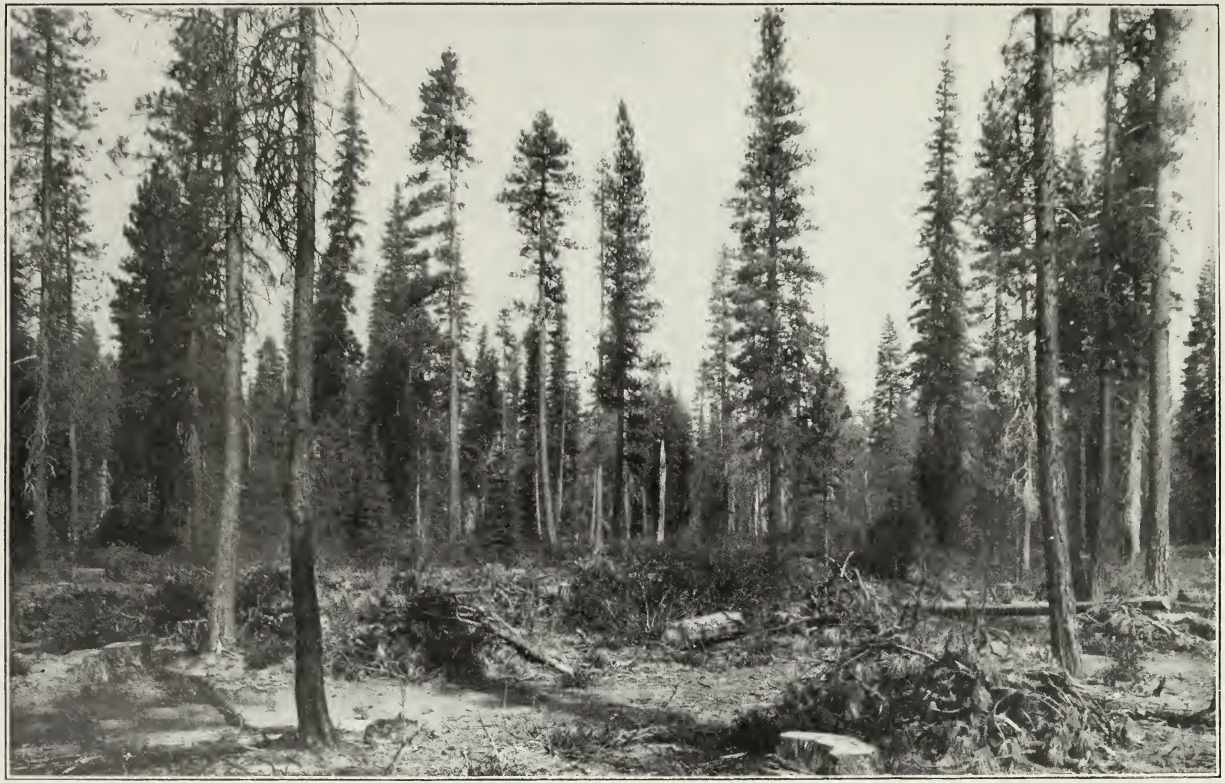
FOREST MANAGEMENT OF PUBLIC LANDS.

It is the policy of the Federal Government to administer the public forest lands in such a way as to perpetuate the forest on all the land which is better suited to the production of timber than anything else, and to make it yield for all time the greatest quantity and the best quality of timber.

The perpetuation and proper utilization of the public forests of yellow pine, i. e., the practice of forestry on these lands, consists of four lines of work: (1) The protection of the virgin forest from fire; (2) the cutting of the mature trees in such a way that the immature trees will be spared from injury; (3) the intensive utilization of all the merchantable timber designated for cutting; and (4) the proper disposal of the logging débris in order to make possible the subsequent protection of the stand of immature timber from fire.

PROTECTION OF THE VIRGIN FOREST FROM FIRE.

It has been shown that the normal yellow-pine forest in Oregon is many-aged and that it should have an abundance of trees of the younger age classes along with the old trees. Absolute fire protection of the virgin woods is necessary, therefore, not alone to prevent the damage or killing of commercial trees, but to prevent depreciation in the future yields.



A MIXED STAND ON THE NATIONAL FOREST IN KLAMATH COUNTY, OREG., WHICH HAS BEEN CUT OVER RECENTLY UNDER THE SELECTION SYSTEM, ILLUSTRATING THE KIND OF IMMATURE TREES THAT MAY BE RESERVED FOR A SECOND CROP.

The brush has been piled but not yet burned.

Ordinarily, a fire in yellow-pine woods is comparatively easy to check. Its advance under usual conditions may be stopped by patrolmen on a fire line a foot or so wide, either with or without backfiring. The open character of the woods makes the construction of fire lines relatively easy, and in many places horses may be used to plow them. The first consideration is to remove the causes of fires, and the second is to detect at their incipiency those that do start, so that they may be suppressed before they have spread to an unwieldy size. With a system of lookouts and patrolmen, a convenient supply of tools and laborers, a reasonably quick means of getting fire fighters to all parts of a tract, and with the exercise of care not to start fires, it is possible, at reasonable cost, to eliminate forest fires larger in extent than a few acres from most of the yellow-pine forests of Oregon. In a few particularly brushy areas, such as the southern Cascades and Siskiyou Mountains, these precautions will give less assurance of success.

The following are samples of the provisions of proved practicability which are placed in contracts between the Government and permittees who are operating on the National Forests.

> In order to check the spread of forest-tree diseases and to eliminate snags which constitute a fire menace, we agree to cut all trees or snags marked upon the sale area whether merchantable or apparently unmerchantable; provided, however, that the number of such trees and snags to be so cut shall not exceed an average of 2 per acre for the whole area included in the sale. * * *
>
> During the period from May 1 to October 1 of each year all locomotives, donkey engines, or other steam-power engines shall burn oil or shall be equipped with spark arresters acceptable to the forest officer in charge, with a connected steam force pump with not less than a 1-inch discharge, 100 feet of serviceable 1-inch fire hose, six 12-quart pails, 6 shovels, and a constant supply of not less than the equivalent of 12 barrels of water, this equipment to be suitable for fire-fighting purposes, and kept in serviceable condition. During this period the purchaser may be required in the discretion of the forest supervisor to patrol all railroad tracks after the passage of each locomotive.
>
> No refuse shall be burned during the period from June 1 to October 1 of each year without the written consent of the forest supervisor.
>
> Whenever necessary in the judgment of the forest officer, the purchaser shall clear and keep clear the railroad rights of way of all inflammable material, including snags and dead trees, for a distance of not to exceed 100 feet on each side of the center of main and spur tracks, in such manner and at such times as may be designated by the forest officer in charge.

CUTTING THE MATURE TIMBER.

Many of the trees in the virgin woods, though large enough to be merchantable, are not mature or "ripe" (bull pines, so called), and should not be cut until they reach their maximum volume productivity and best quality.

The sudden removal of the forest cover in this dry climate is apt so to expose the soil to sun and desiccating winds that its productive capacity would be lessened, making difficult or impossible the starting of reproduction, a serious condition if there is not enough advance reproduction on the ground.

Yellow pine in its middle life and old age demands so much light and ground space that the soil is put to the most intensive use only when the forests are uneven-aged, so that the younger trees may pass their slow-growing sapling stage in the gaps between the big trees.

The system of cutting which seems to be ideal for this type of forest is a form of selection cutting. Periodic cuttings are made, in each of which all the overmature and thoroughly ripe trees in the stand and all the defective ones are removed; and the saplings, poles, and young, thrifty trees are left standing to form the basis for the next crop. No tree is removed until it has reached its majority, so to speak, and no old, slow-growing tree is allowed to stand and occupy space which should be devoted to young and rapid-growing trees. In this way the forest is kept at its maximum productivity and the continuity of the forest cover is not interrupted. In each cutting, under the practice of the Forest Service in Oregon, from 10 to 30 per cent of the volume of the stand (above 12 inches in diameter) is left. This is equivalent to 55 per cent of the trees over 12 inches in diameter by number. It is anticipated that a cutting of this character may be made at intervals of from 40 to 60 years, and that there will be a yield sufficient to justify logging.

Each tree which is to be cut is marked or "blazed" with an ax by a woodsman who has experience, a trained eye, and good judgment. He decides for every tree as he passes through the forest whether it shall be cut or reserved. A woodsman may effectually mark in a day 40 acres, or half a million feet. It is customary to set an approximate diameter limit of from 16 to 22 inches, the majority of the trees above which limit are cut, and those below left; in actual practice this diameter limit must be very elastic, it often being wise silviculturally to reserve a tree 30 or more inches in diameter while one of 14 inches must be cut.

The following classes of trees should be cut. They are arranged according to the desirability of their removal:

(*a*) All spike-topped, seriously fire-scarred, lightning-struck, or otherwise defective, yet merchantable, trees.

(*b*) All insect-infested and conky trees.

(*c*) All suppressed trees which apparently would not thrive and make good growth even if released.

(*d*) All thoroughly mature trees of all species which apparently will not survive until the next cutting. (In this class should be included all trees liable to windthrow, which is a serious menace on certain sites.)

(*e*) Enough of the younger trees which would probably survive until the next cutting to give the remaining trees plenty of room for optimum growth and allow the saplings and seedlings to receive overhead light.[1] The cutting, therefore, should be in the nature of an improvement cutting. Though the trees that are left are not reserved as seed trees, but rather as the basis for the next cut, many of them are large enough to produce seed, and will serve for this purpose in case an accidental surface fire gets into the cut-over area and kills off the advance reproduction of seedlings and small saplings.

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[1] Manuscript report by Forest Supervisor M. L. Merritt.

Where the yellow pine occurs in small groups in which all the trees are of an even age, the cutting should be to a certain extent groupwise, it being an object to cut out *in toto* the groups of very old trees and leave almost intact the groups of very thrifty trees. The clean-cut gaps should not be made large, since it is wise not to open up the stand too heavily and allow drying winds to get at the soil, or chaparral to come in and occupy the ground to the exclusion of young yellow pines.

While the selection method of cutting makes the cost of logging a little greater than it would be were every merchantable tree cut, this increase is partly, if not wholly, compensated for by the fact that the average value of the trees cut by this system is higher. The "bull pines" that are left, though merchantable, are so heavy, knotty, and sappy that they are not so profitable for the lumberman to pay stumpage for and to manufacture as the older "yellow pines." In Appendix C (see p. 46) are given, in full, "Instructions for marking timber in the yellow-pine region, District 6," which are in effect in the administration of timber sales on the National Forests of Oregon. In contracts for the sale by the Department of Agriculture of yellow-pine stumpage, clauses similar to the following are being used in order to provide for the cutting of the timber by the permittees according to the methods described above:

> It is agreed that this sale includes all the merchantable dead timber standing and down on the areas designated for cutting by the forest officer, and not less than 85 per cent by volume of the total stand of merchantable live timber in trees 12 inches and over in diameter at a point 4½ feet above the ground on such designated areas, to be marked for cutting by the forest officer in charge.
>
> No unnecessary damage shall be done to young growth or to trees left standing, and no trees shall be left lodged in the process of felling. Unmarked or undesignated trees which are badly damaged in logging shall be cut if required by the forest officer in charge.
>
> All marked trees shall be cut. No live timber shall be cut except that marked.

INTENSIVE UTILIZATION.

One of the essentials of forestry is to secure a close utilization of the forest: to cut all merchantable dead trees and all living trees that are ripe for the ax; to cut the inferior species along with the major species, so that the forest may not degenerate; to use each tree intensively, so that there may be no waste in high stumps, large tops, or in partly defective yet usable portions of the tree. To secure this conservative intensive use, provisions similar to the following are introduced in National Forest timber-sale contracts, and they are proving to be both effective and practical:

> All cutting shall be done with a saw when possible; stumps shall be cut so as to cause the least practicable waste, and not higher than 18 inches on the side adjacent to the highest ground, except in unusual cases when, in the discretion of the forest officer in charge, this height is not considered practicable; all trees shall be utilized to as low a

diameter in the tops as practicable so as to cause the least waste, and to a minimum diameter of 7 inches when merchantable in the judgment of the forest officer in charge. The log lengths shall be varied so as to make this utilization possible.

All yellow-pine logs are merchantable under the terms of this agreement which are not less than 10 feet long, at least 8 inches in diameter inside bark at the small end, and, after deductions for visible indications of defect, scale 33 per cent of their gross scale. * * *

DISPOSAL OF THE LOGGING DÉBRIS.

The brush left after logging decays slowly in the dry climate of eastern Oregon, and the fire season is long. Slashings on which the brush is not disposed of properly are serious fire menaces. If they become ignited they make a bad fire which is apt to destroy all the young trees so carefully reserved in the logging and those which have sprung up afterwards. The brush should be piled as the logging proceeds, in small compact piles, away from the bases of reserved trees and as far as possible from groups of reproduction. When the piles become dry enough and the season is such that there is no danger of a general conflagration, preferably in the late fall, the piles should be burned. The danger of a severe fire within the next few years is then practically removed. The cost of lopping the larger pieces of débris and piling all the brush in a thorough fashion amounts to somewhat less than 25 cents for each thousand feet of timber logged, and the cost of burning it amounts to a few cents more.

Besides creating a security against fires, the piling and burning of the brush has added advantages; it makes the logging decidedly easier, since, if the piles are properly located, the teamsters and horses can more readily get to the logs to haul them out, and it also tends to prevent the inordinate increase of bark beetles and other insect enemies that breed freely in logging débris.

In exceptionally dry situations where reproduction is scanty and has difficulty in becoming established, as on the pumice soils of the Klamath-Deschutes divide, it may be better forest management to scatter the brush as a mulch over the surface of the ground, in order that it may assist in preventing the evaporation of moisture from the soil and in shielding the young seedlings from hot sun, dry winds, and frost. The method is being tried on a small scale experimentally by the Forest Service at the present time and is used quite generally in the Southwest, where the fire risk is less and reproduction is difficult. But it should be used only in localities where the fire risk is small, as where the trees are scattered and the brush does not make a continuous or heavy cover. At all events, fire lines or strips on which all the brush is burned should be built, so that should a fire get into the débris it could be confined to a small area.

To enforce the proper disposal of the slash on sales of stumpage on the National Forests, a clause such as the following is being used in the contracts with the permittees:

Tops of all trees felled, whether merchantable or nonmerchantable, shall be lopped, and all brush piled compactly at a safe distance from living trees, as directed by the forest officer in charge.

FOREST MANAGEMENT OF PRIVATE LANDS.

At the present time yellow-pine stands on privately owned lands in Oregon are usually logged with no thought of securing a second crop of timber on the land cut over. All the merchantable timber is cut, the brush is allowed to lie where it falls, and the area is given no protection from fire. As a result, fire usually gets into these slashings and consumes many of the seedlings and saplings which were on the ground as "advance reproduction" before the cutting. There being no seed trees, the area does not reforest, but remains unstocked, or inadequately stocked, practically an unproductive waste of idle land. Such land is usually retained by the owner because it yields a rental for grazing purposes, which about equals the taxes upon it.

A part of the yellow-pine land which has been cut over already is adapted to agriculture, and therefore it has quite naturally been an object of the owner to remove the timber in such a way as to annihilate the forest. But the majority of the yellow-pine land in the State is absolute forest land; i. e., it is too dry, or too rocky, or too steep, or at too high an altitude for agriculture and is land which serves its greatest usefulness in the production of forest crops. Where such absolute forest land has become reforested after destructive lumbering, it has been by chance rather than by the intent of the operator.

It has been necessary up to the present time, because of economic conditions, that the logging should be of a destructive nature. However, with the rapidly increasing value of stumpage the probability of reform in timberland taxation, the greater security against forest fires, and the increased stability and confidence in timberland investment, it can be said confidently that the time is here when the yellow-pine timber operator in Oregon can afford to do something toward conducting his logging operations and handling his cut-over lands so that they will remain productive of forest crops. The Government can afford to leave standing from 10 to 30 per cent of an uneven-aged forest as the basis of a second cut, and allow it to grow for 50 or 60 years, but the individual owner can not afford to tie up an investment in slow-growing timber for this length of time unless a speculative rise in the value of the reserve stumpage be counted upon. In short, the individual owner must take off the tract all the timber that he can market at a profit in order to defray his logging and fixed charges and to get back his invested capital; but even if he must cut off of the tract all the merchantable trees, and can not follow the method practicable on public lands, there are several measures which he can adopt to promote the growth of future crops of timber and to make the tract more valuable. The raising of such a second crop is in no wise incompatible with the use of the land for grazing.

1. He can protect the virgin woods from fire. This is being done with fair success now on many private holdings in the State, and all the indications are that it will be universal and effective throughout the yellow-pine region of Oregon before many years.

2. He can conduct the logging so that the seedlings and saplings, small poles, and occasional large unmerchantable yellow pines which are present in all stands will be spared and protected against forest fires. Misshapen or undersized yellow pines which it will not be financially profitable to handle may be allowed to stand, for such trees may make useful seed trees. Sometimes loggers now cut 10-inch and 12-inch "bull pines" which are so small and yield such sappy, knotty lumber that it is doubtful if their contents pay for their handling. If such trees were left standing, the owner would be out nothing and yet would have his land in better condition for producing a second forest crop; and this would enhance its value even though the second crop should not be as good as would be obtained under a conservative selection method of cutting.

3. Every tree both dead and alive of all species should be utilized, both in the woods and in the mill, to the utmost degree of practicability. The saving effected by intensive utilization may help to defray the cost of brush disposal.

4. The brush should be piled and burned or otherwise disposed of, so that the area will be immune from subsequent destructive fires. Disposal of the brush will also benefit the grazing. The State law now requires all slashings to be burned each year.[1]

It may be assumed that the first recommendation will be observed anyway by all timberland owners. Of the last three provisions, the disposal of the brush is the only one that should cost the operator or owner anything, and this piling and burning costs but little more than the slash burning required by law of all timberland owners and operators throughout the State. It is believed that the small amount of money spent in brush piling and burning (perhaps 30 cents for each thousand feet cut) is a good investment for the timberland owner and will repay him in—

(*a*) Increased ease in logging.
(*b*) Improved range for stock.
(*c*) Added safety of surrounding uncut timber and of adjoining logging investments against fire.
(*d*) Insurance of the young reserved seedlings and poles (the oncoming crop) against disastrous fires during the next few years.

The observance of these simple principles, which require no revolution in present logging methods, and which add but a trifle to the present logging costs, seems well worth while for the owner who is operating in yellow pine and is planning to hold his cut-over land anyway. Cut-over land which has a second crop started should be worth more some years hence than land that is absolutely denuded. And if this second crop is secured without cost other than the charges of holding the land, any increase in the value of the land on account of its second crop is net gain.

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[1] Chapter 278, section 11, Laws of Oregon, 1911.

APPENDIX A.

THE BLUE MOUNTAIN VOLUME TABLE FOR WESTERN YELLOW PINE.

This volume table is based on the measurement in 1910 of 1,536 felled western yellow pines which had grown under average conditions in northeastern Oregon in Union, Baker, and Grant Counties. It is a combination of the Austin, Oreg., and the Lookingglass Creek, Oreg., volume tables. The trees were scaled by the Scribner rule according to Forest Service usage, the stumps being never higher than the diameter of the tree at breastheight, the trees being utilized as thoroughly as practicable, but not to less than 6 inches diameter inside bark at top of last log, the logs being cut into 16, 14, or 12 foot lengths and 2 inches being allowed for trimming on each log. No allowance was made for decay, breakage, or other abnormal defect. All volumes evened off on curves.—T. T. Munger and G. A. Bright.

Diameter at breast-height.	Number of 16-foot logs.														Average of all heights.	Average diameter inside bark, top of last log.
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½		
	Volume of tree, in board feet, Scribner rule.															
Inches.															*Bd. ft.*	*Inches.*
10	35	50	65												50	6.3
11	50	65	80												65	6.2
12	65	80	95	120											90	6.5
13	80	95	115	140	170	210									125	6.4
14	95	110	130	160	195	230	285								160	6.5
15	110	130	150	180	215	260	315								200	6.4
16	130	150	180	200	240	290	340	400	470						245	6.7
17	150	170	200	225	270	315	375	435	500						295	6.7
18		195	220	255	300	350	405	465	535	630					350	6.6
19		225	255	290	335	385	440	505	575	665					410	6.8
20		260	290	325	365	415	470	535	610	705	820				480	6.9
21				385	415	455	510	575	655	750	865				560	6.8
22				440	475	515	565	630	705	800	915	1,050			645	7.0
23				500	530	570	620	680	760	855	970	1,100			740	7.0
24					595	630	680	745	820	915	1,030	1,170			840	7.2
25					655	700	755	820	900	1,000	1,115	1,260			940	7.3
26					720	765	825	900	985	1,090	1,210	1,340			1,050	7.4
27					800	855	915	990	1,080	1,180	1,300	1,430	1,570		1,170	7.3
28					885	940	1,010	1,090	1,190	1,300	1,420	1,560	1,700		1,300	8.1
29					985	1,040	1,120	1,210	1,310	1,430	1,550	1,690	1,830		1,440	7.9
30					1,090	1,160	1,250	1,340	1,450	1,570	1,700	1,840	1,990		1,590	8.0
31						1,260	1,360	1,470	1,590	1,720	1,860	2,010	2,160	2,330	1,750	8.5
32						1,370	1,470	1,600	1,730	1,870	2,020	2,180	2,340	2,520	1,920	8.5
33							1,620	1,750	1,890	2,040	2,200	2,370	2,550	2,740	2,090	8.5
34							1,760	1,910	2,060	2,220	2,380	2,560	2,740	2,960	2,270	9.4
35							1,920	2,080	2,240	2,410	2,580	2,760	2,950	3,160	2,450	9.3
36							2,100	2,250	2,410	2,580	2,760	2,950	3,150	3,360	2,630	11.7
37							2,260	2,420	2,580	2,750	2,940	3,140	3,360	3,580	2,820	8.9
38							2,410	2,560	2,740	2,930	3,130	3,330	3,560	3,800	3,000	11.1
39								2,700	2,880	3,080	3,280	3,500	3,750	4,000	3,170	13.6
40								2,840	3,030	3,240	3,460	3,690	3,940	4,220	3,330	12.9
41								2,960	3,170	3,380	3,610	3,850	4,100	4,400	3,480	16.8
42								3,080	3,290	3,510	3,740	3,990	4,250	4,580	3,630	9.4

APPENDIX B.

THE KLAMATH VOLUME TABLE FOR WESTERN YELLOW PINE.

This volume table is based on the measurement in 1910 of 823 felled western yellow pines which had grown under average conditions in southwestern Klamath County, Oreg., most of them in the vicinity of Pelican Bay and some near Keno and Meadow Lake. The trees were scaled by Scribner rule according to Forest Service usage, the stumps being never greater than the diameter of the tree at breastheight, the tree being utilized as thoroughly as practicable but not to less than 6 inches inside the bark at top of last log, the logs being cut into 16-foot lengths or less, and 2 inches being allowed for trimming on each log. The third from the last column shows, for trees of each diameter class, all heights being averaged together, the actual volume which was utilized in trees cut in Forest Service sales near Pelican Bay, allowance having been made for basal scars, visible decay, and unavoidable wastage in falling. The next to the last column shows the percentage by which this actual available volume is less than the possible merchantable volume. Volumes evened off on curves.—T. T. MUNGER and H. A. WINKENWERDER.

Diameter at breast-height.	Not allowing for decay, breakage, or other abnormal defect.															Allowing for basal scars, visible decay, and unavoidable waste in falling.		Average diameter inside bark top of last log.
	Number of 16-foot logs.														Average of all heights.	Average of all heights.	Percentage of allowance.	
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½				
	Volume of tree in board feet, Scribner rule.																	
Inches.															*Bd. ft.*	*Bd. ft.*		*Inches.*
12	80	85	95												85	85		
13	80	90	100												90	90		
14	85	95	110												105	105		7.1
15	90	105	120	145	175										140	140		6.9
16	95	115	135	160	200	245	300								185	185		6.6
17		130	150	185	225	275	330								240	240		6.6
18		150	170	210	255	315	370	455	545						300	300		6.8
19		175	195	245	295	355	415	495	595						355	355		6.8
20		205	225	280	335	400	465	545	645	765					415	415		7.2
21		235	260	320	375	450	520	600	710	830					485	480	1.0	7.2
22				375	430	505	580	665	780	900					565	555	1.8	7.3
23				435	490	565	645	735	850	980					655	640	2.3	7.4
24				500	555	630	710	805	920	1,055	1,140	1,190			750	730	2.6	8.1
25				575	630	705	780	885	1,005	1,130	1,220	1,275			855	825	3.5	7.8
26				655	710	785	870	980	1,090	1,220	1,310	1,360			965	930	3.6	7.8
27				740	805	880	965	1,080	1,195	1,320	1,400	1,450			1,085	1,040	4.1	8.5
28				830	900	980	1,070	1,180	1,300	1,420	1,495	1,550	1,600		1,215	1,160	4.5	7.5
29				925	1,000	1,090	1,185	1,295	1,410	1,515	1,585	1,645	1,695		1,350	1.280	5.2	7.6
30						1,200	1,305	1,410	1,515	1,610	1,685	1,745	1,805		1,490	1,410	4.9	8.7
31						1,310	1,400	1,515	1,620	1,715	1,795	1,870	1,935		1,635	1,550	5.2	8.4
32							1,500	1,620	1,730	1,835	1,925	2,010	2,090	2,170	1,790	1,705	4.8	8.9

33	....	....	....	....	....	....	1,600	1,745	1,870	1,990	2,090	2,180	2,260	2,330	1,950	1,870	4.1	8.7
34	....	....	....	....	....	....	1,700	1,880	2,025	2,150	2,260	2,350	2,420	2,500	2,120	2,040	3.8	8.8
35	....	....	....	....	....	....	1,800	2,000	2,160	2,300	2,420	2,520	2,610	2,690	2,295	2,220	3.3	8.6
36	....	....	....	....	....	....	1,900	2,125	2,305	2,470	2,600	2,720	2,830	2,920	2,480	2,410	2.9	9.4
37	....	....	....	....	....	....	2,020	2,250	2,460	2,640	2,800	2,930	3,050	3,160	2,670	2,600	2.3	10.8
38	....	....	....	....	....	....	2,180	2,430	2,640	2,860	3,040	3,180	3,310	3,440	2,865	2,790	2.6	10.3
39	....	....	....	....	....	....	2,350	2,640	2,890	3,110	3,280	3,440	3,580	3,730	3,070	2,980	2.3	11.1
40	....	....	....	....	....	....	2,530	2,860	3,140	3,360	3,550	3,730	3,880	4,040	3,280	3,180	2.9	12.3
41	....	....	....	....	....	....	2,740	3,090	3,360	3,610	3,820	4,010	4,180	4,350	3,500	3,390	3.2	11.9
42	....	....	....	....	....	....	2,980	3,280	3,570	3,840	4,080	4,300	4,500	4,690	3,750	3,620	3.7	9.7
43	....	....	....	....	....	....	3,200	3,506	3,780	4,060	4,320	4,585	4,820	5,050	4,030	3,870	3.9	12.0
44	....	....	....	....	....	....	3,420	3,720	4,010	4,310	4,600	4,880	5,140	5,400	4,340	4,140	4.6	10.6
45	....	....	....	....	....	....	....	....	4,240	4,560	4,880	5,170	5,450	5,700	4,660	4,450	4.5	12.6
46	....	....	....	....	....	....	....	....	....	4,800	5,120	5,440	5,730	5,990	5,000	4,800	4.0	12.6
47	....	....	....	....	....	....	....	....	....	5,000	5,360	5,680	5,980	6,280	5,320	5,160	3.2	12.7
48	....	....	....	....	....	....	....	....	....	....	5,600	5,920	6,230	6,540	5,600	5,480	2.2	13.2
49	....	....	....	....	....	....	....	....	....	....	5,810	6,130	6,450	6,760	5,860	5,720	2.4	13.6
50	....	....	....	....	....	....	....	....	....	....	6,000	6,340	6,660	6,970	6,080	5,880	3.3	14.4

APPENDIX C.

INSTRUCTIONS FOR MARKING TIMBER IN THE YELLOW PINE REGION, DISTRICT 6.

East of the Cascade Mountains in Oregon and Washington, the commercial forests, consist largely of yellow pine, either in pure stands or in mixed stands with Douglas fir, white and grand fir, western larch, and lodgepole pine.

Since these forests are primarily uneven-aged, they should be managed by the selection system (or a modified form of the selection system). It should be the aim, therefore, to cut over each portion of these forests periodically. From the data now at hand it is evident that the period between cuttings (the cutting cycle) should be about 60 years, and that no trees should be cut until they are 180 years old; i. e., the rotation should be 180 years.

The following general principles should govern the marking of timber in forests of this region:

GENERAL PRINCIPLES FOR ALL TYPES.

1. The cutting should be fundamentally an improvement cutting; and the officer who is marking the timber should decide first what is to be left, and then mark for cutting what is not reserved. His aim should be to leave the forest in the best condition for development during the coming cutting cycle, so that it will produce a good crop in the next cutting.

2. Aim to mark for cutting the thoroughly mature trees of all species and all those which will not survive and make good growth until the next cutting, 60 years hence.

3. Aim to reserve as the basis for the next crop a well-distributed stand of thrifty saplings, poles, and young standards, each of which is capable of living and growing until the next cutting. The trees which are reserved should be considered not as "seed trees," but as the nucleus of a later cutting.

4. On the average from 20 to 25 per cent of the estimated volume of the trees over 12 inches in diameter should be reserved. Where most of the timber is thoroughly mature or decadent, it may be wisdom to leave a smaller percentage; where most of the timber is young and thrifty, a much larger proportion should be reserved. In general, make the cutting as light as is consistent with allowing the logger to do practical, profitable logging, aiming thereby to extend the improvement cutting over a larger area, instead of making it a heavy cutting on only a small area.

5. An area should not be included within the limits of a timber sale in which there is not enough mature timber to make it worth the while of the logger to go into that area for the mature timber alone, thereby necessitating marking immature timber in order to make the logging profitable.

6. Do not hesitate to make the marking somewhat groupwise, if all the trees over a certain area are thoroughly ripe, except in exposed situations where gaps in the forest canopy are not desirable or where there is danger that the reproduction will be endangered. Yellow pine occurs to some extent even-aged in groups; and it will be necessary often to remove the old groups in their entirety. Avoid, however, making a clearance over an area larger than an acre.

7. Mark for cutting the following classes of trees of all species throughout the region in the following order of preference:

   (*a*) All spike-topped, seriously fire-scarred, lightning-struck, or otherwise defective yet merchantable trees. Do not, however, consider that every tree that has a fire scar or a thin crown or some other deformity has got to be removed. Few perfect trees are to be found, and small basal scars or similar injuries in no way impair the health of the trees.

   (*b*) All insect-infested trees.

   (*c*) All suppressed trees which apparently would not thrive and make good growth even if released.

   (*d*) All thoroughly mature trees of all species which apparently will not survive until the next cutting.

8. In general, the species should be favored in marking in the following order of preference: Western yellow pine, sugar pine, western larch, Douglas fir, white (or grand) fir, and lodgepole pine. The last two species should be considered forest weeds, and always marked heavily where better species are present.

The forests of this region may be, for the convenience of discussion, grouped into three classes: (A) practically pure stands of yellow pine; (B) mixed stands in which there is a good deal of yellow pine; (C) mixed stands in which there is little or no yellow pine. The marking in each type involves some considerations peculiar to that type.

A. *Practically pure stands of yellow pine.*[1]—This classification occurs on the slope type of the region east of the Cascades, and includes most of the commercial timber of this region. In addition to the kinds of trees mentioned above, in this type the following classes of yellow pines should also be removed:

1. Such of the mature yellow pines as would probably survive until the next cutting, when there is a superabundance of such trees to leave as the basis for the next cutting and to insure reproduction.
2. Young yellow pines, "bull pines," where the thinning out of a congested group is advisable.

B. *Mixed stands with some yellow pine.*—This is the kind of timber that is characteristic of the north slope subtype in the Blue Mountains. This class of land is well adapted to the growth of yellow pine; and, therefore, this species should be favored in marking in preference to all other species. Yet the species of secondary importance, Douglas fir and western larch, should not be marked heavily except where by so doing young yellow pines already in the stand will be directly benefited. This practice is advisable for two reasons: (1) At the present time Douglas fir and western larch in yellow-pine sales are undesirable to the purchaser and do not bring a price commensurate with what they will be worth in the future, and (2) it seems better to mark these secondary species lightly now and have the assurance of an early second cut than to make a heavy cutting now and as a result not obtain a second cut until the remote future, even though by the heavier cutting more yellow pine might be gotten into the future stand. In other words, do not sacrifice now any thrifty Douglas fir and larch unless the silvicultural conditions and composition of the forest is going to be directly benefited. The marking, therefore, should conform to the following principles, supplementing those under "General Principles:"

1. Consider white fir, grand fir, and lodgepole pine as forest weeds to be marked to as low a diameter as is consistent with the terms of the timber-sale contract and justice to the purchaser, both in order to strive to decrease the proportion of these species in the forest and to give place to more desirable species.
2. Consider Douglas fir and western larch not as undesirable species, but as species of secondary value.

Therefore, mark only such thrifty Douglas fir and larch as are in active competition with good yellow pines, or with superior Douglas firs and larches. For example, where a Douglas fir (or larch) and a yellow pine, both thrifty and of the same character, are growing side by side, one to be reserved and the other removed, the yellow pine should be reserved and the species of secondary value cut. In choosing between a Douglas fir and a larch, preference should be shown the larch except in situations not well adapted to this species.

C. *Stands with little or no yellow pine.*—This is the kind of timber which is typical of the transition type. Since in this type there is practically no yellow pine, stands of this character are ordinarily not included in the timber sales in the yellow-pine region except in cases where some of this type forms an inseparable part of the logging unit.

In general the procedure in marking should be the same as under "General Principles" and under "B" with these provisions:

1. Mark the inferior species—white fir, grand fir, and lodgepole pine to a low diameter limit, except that where these inferior species compose practically the whole stand, leave the thrifty trees of these species in preference to making a clearance.
2. Mark only such trees of the desirable species as would not thrive for the next 60 years and such as are a detriment to their superior associates.

APPENDIX D.

INSTRUCTIONS FOR BRUSH BURNING UNDER THE SELECTION SYSTEM OF CUTTING IN DISTRICT 6.

In most cases where the selection system is practiced in this district, i. e., throughout the yellow-pine type and most of the mixed forest types east of the Cascades, the brush is piled and burned in logging operations on the National Forests. The following instructions are issued in regard to methods of brush piling and burning, in order that this most vital and far too often poorly managed part of our administration of selection cuttings may be handled in the best possible fashion.

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[1] Since sugar pine so closely resembles yellow pine in value and silvical requirement, it is adapted to the same method of treatment as the yellow pine with which it is associated.

Piling brush.—The first step in successful brush disposal is to secure good piles, and this requires the observance of the following provisions:

1. The large limbs should be lopped off the tops, so that, where piles are made on the tree tips, the brush will lie compactly.
2. Piles should be placed as far as possible from reserved trees of all sizes and from patches of reproduction of all species.
3. Piles should be made medium in size; i. e., they should not be so large that they will make a dangerously large blaze, and they should not be so small that they will be unnecessarily costly to burn or cover an unnecessarily large proportion of the ground.
4. The débris should be laid on the piles in an orderly fashion, so that they will be compact. The piles should be *piles*, and not heaps of brush.
5. Large chunks, and heavy limbs free from twigs, should not be placed on the piles. Such pieces will not burn up completely, and, if charred, will not rot quickly.

Burning the piles.—The success of the selection method of cutting as practiced in the yellow-pine region depends upon the proper burning of the brush. If it is not well done, the sale will be bad silviculturally no matter how good the marking or how much care is taken to avoid damage to reproduction and reserved trees. In order to burn the piles so that the least possible damage to the forest will be done, the following points should be observed, whether the burning is done by the purshaser under the direction of the forest officer or directly by the Forest Service.

1. Each burning crew should consist of but four or five men, who should be in charge of an intelligent, careful foreman. In every case there should be a forest officer to each two crews, and he should be on the ground supervising the burning most of the time while it is in progress.

2. The lighting of the piles should be done only by the foreman or some other responsible member of the crew, who will use good judgment in applying the torch.[1] At times when the brush is apt to burn freely, only every other or every third or fourth pile should be lighted, and the balance burned later or on another day, and thus the intense heat caused by burning consecutive piles will be avoided and the danger of a general conflagration lessened. Account should also be taken of the direction of the wind in relation to reserved trees, and the torch used with discretion accordingly.

The balance of the crew should "chunk up" the piles, so that a rim of unburned limbs, twigs, and needles will not be left, and should with shovels confine the fire to the space immediately about the piles.

3. The foremost consideration in brush burning is to lessen the fire menace from the logging débris in such a way that as little as possible of the reserved timber and young growth will be hurt. It is not necessary, therefore, to burn every pile, for when an occasional pile is of necessity close to young trees, it is far better to leave it than to burn it and damage them. It is also unnecessary to burn the brush absolutely clean to a bed of ashes. The coarser pieces are not a fire menace so long as all the fine twigs and needles are consumed, and though unsightly for a year or two they are not so much so as a group of scorched or dying poles and saplings. It is usually better silviculturally to have the piles burn moderately than to have them burn fiercely, and the increased cost of slow burning is amply justified.

4. In general, the fall is the best season for brush burning in practically every part of the district. On all sales, therefore, all the brush piles which have accumulated to date should be burned in the fall and early winter. In large sales where logging is in progress during the winter and early spring, in order to avoid carrying through the dry season a large quantity of brush piles, it may be best to do some spring brush burning. In any event, where a large quantity of brush is on hand in the spring, strips of brush piles should be burned for fire lanes. Begin fall burning as soon as the woods are wet enough, and spring burning as soon as the piles are dry enough. The burning seasons are short and should be made the most of.

5. The key to successful brush burning is the selection of exactly the right time to do the burning. When the season is right for burning, prompt action should be taken to get the burning crew on the ground. The weather for each day must be considered. On windy days or during the hot middays, if the burning can not be done without danger or damage to young growth, it must be discontinued until conditions are right. On some steep brushy slopes, burning may be safe only when the brush is rather wet or when snow is on the ground. In short, use judgment in selecting the day and the time of day for burning each part of a slashing; i. e., do it only at such times as will insure the best silvicultural results, and the administration of the crew should be so arranged as to accomplish this, even though to do so increases the cost of the brush disposal.

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[1] A convenient brush-burning torch has been devised by one of the supervisors. It consists of a piece of light 2-inch pipe, 18 inches long, with a detachable cap or headstop at one end, which is fitted through a reducer to a piece of $\frac{3}{8}$ or $\frac{5}{8}$ inch pipe 30 inches long. Through the small pipe is run a cotton wick of the same size, its lower end being bent into convenient shape. The large pipe answers as a tank and will hold 1 quart of coal oil.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 419

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ November 9, 1916

THE GRAPE LEAF-FOLDER.

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INTRODUCTION.

The grape leaf-folder, *Desmia funeralis* Hübn. (family Pyralidae) has long been known as a pest of grapevines. Since 1885 the injury inflicted by the larva has been described frequently, and different remedial measures have been suggested. However, the insect has not been the subject of very careful study, and references to it in literature are mostly in the form of short notes in farm and horticultural journals.

Certain facts concerning the life history and habits of this insect were obtained during two seasons' observations in the vicinity of the city of Washington.

HISTORY.

The grape leaf-folder first appeared in literature in 1796, when it was figured by Hübner (1)[1] under the name of *Pyralis funeralis*. Switzerland was given for the locality, which was evidently a mistake, as pointed out by Guenée (5, p. 190) in 1854. Later Hübner (2) placed the species in the genus Anania.

In 1832 Westwood (4) established the genus Desmia and placed in it the species *maculalis*, including as a probable synonym *Botys*

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[1] Numbers in parenthesis refer to "Literature cited," p. 13.

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bicolor Swainson (3), which he considers the female of *maculalis.* In 1854 Guenée (5, p. 189) included in the genus Desmia descriptions of both *maculalis* and Hübner's *funeralis*, the latter being taken from Hübner's original figure of the species. Five years later Walker (7) reduced *Desmia maculalis* Westw. to the rank of a synonym, naturally giving *Desmia funeralis* Hübn. priority.

Following is the synonymy of the species:

Desmia funeralis.
  Pyralis funeralis Hübn., Pyral. f. 103, 1796.
  Anania funeralis Hübn., Verz. Schm. 360, 3449.
  Botys bicolor ? Swain., Zool. Illustr. II, pl. 77. 1821–2.
  Desmia maculalis Westw., Mag. Zool. Class IX, pl. 2. 1832.
  Desmia funeralis (Hübn.) Guen., Delt. et Pyral. No. 124, p. 190. 1854.

The history of the grape leaf-folder from an economic standpoint began in 1855 with Glover's (6, p. 78) description of the injury inflicted upon grapevines under glass. The remedy suggested, which has been recommended most often since, was hand-picking and trampling under foot of the folded leaves, thus killing the larvæ. Glover had specimens and records of injury from the District of Columbia, Columbia, S. C., and Atlanta, Ga.

In 1868 Riley (9) gave a short description of the insect and its work and stated that it was of common occurrence in Illinois.

Saunders (10), in his "Insects Injurious to the Grape," mentions having met with a few specimens of the grape leaf-folder in Ontario, Canada.

In 1897 Hoy (11) stated that Desmia, in Wisconsin, was a great pest among the vineyards.

Bulletin 4 of the South Carolina Agricultural Experiment Station (12) states that the insect is very abundant throughout the Southern States; the damage wrought by it, however, is slight. The usual remedial measure, that of crushing the larvæ within the folded leaves, is recommended.

In the same year Woodworth (13) writes that *Desmia funeralis* is an important pest in Arkansas. Here we find the most complete account of the life history to date. Six species of insects parasitic on the grape leaf-folder were obtained, and the author advises keeping the infested leaves, after picking, in a finely screened box in order to afford the parasites an opportunity to escape, but yet retain the hosts, and thus materially aid in the natural control of the pest.

The same author (14, p. 71), two years later, informs us that the station vineyard at the Arkansas Agricultural Experiment Station is badly infested. He notes a difference in the amount of injury inflicted upon different varieties of grape.

Riley (16) again refers to the insect, quoting correspondence showing the leaf-folder to be common in Texas, and Troop (15, p. 74) records the species in limited numbers in Indiana. The latter writer recommends gathering and burning all dead leaves.

Marlatt (17) gives a short account of the insect's life history and recommends the use of an arsenical spray as well as hand picking and clean culture as combative measures.

Smith (19, p. 459) lists *Desmia funeralis* from several localities in New Jersey, and Bogue (18) records two broods of the insect in Oklahoma. Picking the folded leaves is recommended, together with rearing the parasites and allowing them to escape.

Unusual injury by the pest in various localities in Georgia is recorded in the Annual Report of the Georgia Agricultural Experiment Station (20).

Webster and Newell (21), in Ohio, reared the insects, together with a parasite, *Habrobracon gelechiae,* from grape leaves. Washburn (23) records the insect in Minnesota and recommends hand picking. Pettit (24, p. 322) refers to its presence in Michigan.

Quaintance (25) gives a short sketch of the life history of the grape leaf-folder, with treatment, the latter consisting of spraying, hand picking, and clean culture. Vines sprayed with arsenicals for other insects will not be troubled by the leaf-folder.

Essig (26) has recently treated of the pest in California, giving a short account of the life history of the species; arsenical spraying is recommended as a remedy, although the insect has never become economically important in the Far West.

DISTRIBUTION.

Walker (7) gives the distribution of *Desmia funeralis* as United States and Nova Scotia to Orillia, Ontario Province, Canada. According to Marlatt (17) it occurs from New England southward to Florida, and westward at least to the Rocky Mountains. The Atlantic States is given as its range in Dyar's list (21).

In California, according to Essig (26), it occurs in the central part of the State, being most commonly found in the Sacramento and San Joaquin valleys.

It will be seen from the above and from the references given under the history of the species, that *Desmia funeralis* is widely distributed in the United States, covering doubtless all regions where the wild or cultivated grapes grow. It also extends on the north to include a considerable portion of Canada. However, the insect has not as yet, with occasional exceptions, assumed the proportions of a pest of much economic importance outside of the Central States between the latitudes of 35° and 40°.

On the accompanying map (fig. 1) are shown localities in the United States and Canada where the writer has been able to find definite records of its occurrence. However, in States where the map shows only a single record, a search for specimens would doubtless show the species to be present generally.

FOOD PLANTS.

Desmia funeralis feeds principally on the wild and cultivated grape. It has been collected on fox grape, *Vitis labrusca;* southern fox grape, *Vitis rotundifolia;* and *Vitis cordifolia.*

Generally speaking, all varieties of cultivated grapes are liable to attack, though there is some evidence to indicate that the larvæ may show discrimination. According to Woodworth (14) this distinction made by the larvæ between varieties is quite marked, the varieties Agawam, Brighton, Excelsior, Grein's Golden, Highland, Herman, Israella, Jefferson, Jessica, Mary Ann, Lady Washington, Merrimac, Mason Seedling, Requa, Rogers, and others losing more than three-fourths of their foliage, while others lose about one-half. The writer has found in Virginia that the Clinton, Duchess, Martha, Moore's Early, and Amber varieties are particularly attractive to the insect. Varieties with tough leaves are less attractive than those with more tender foliage.

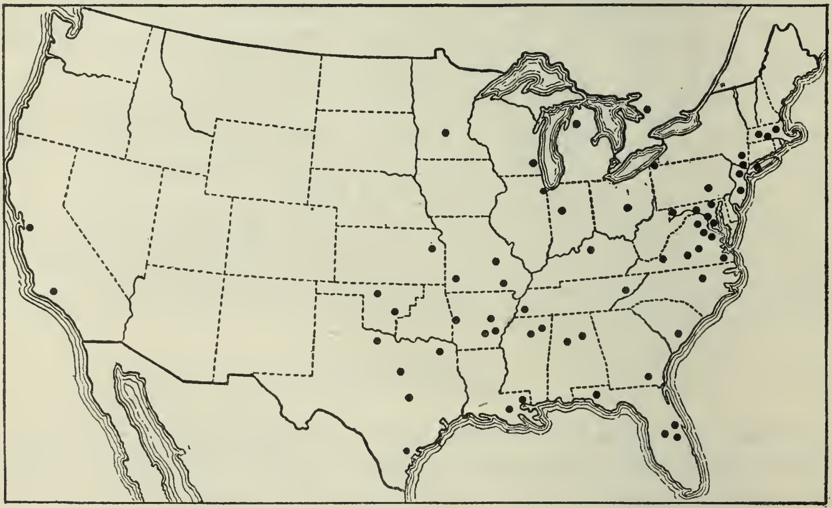
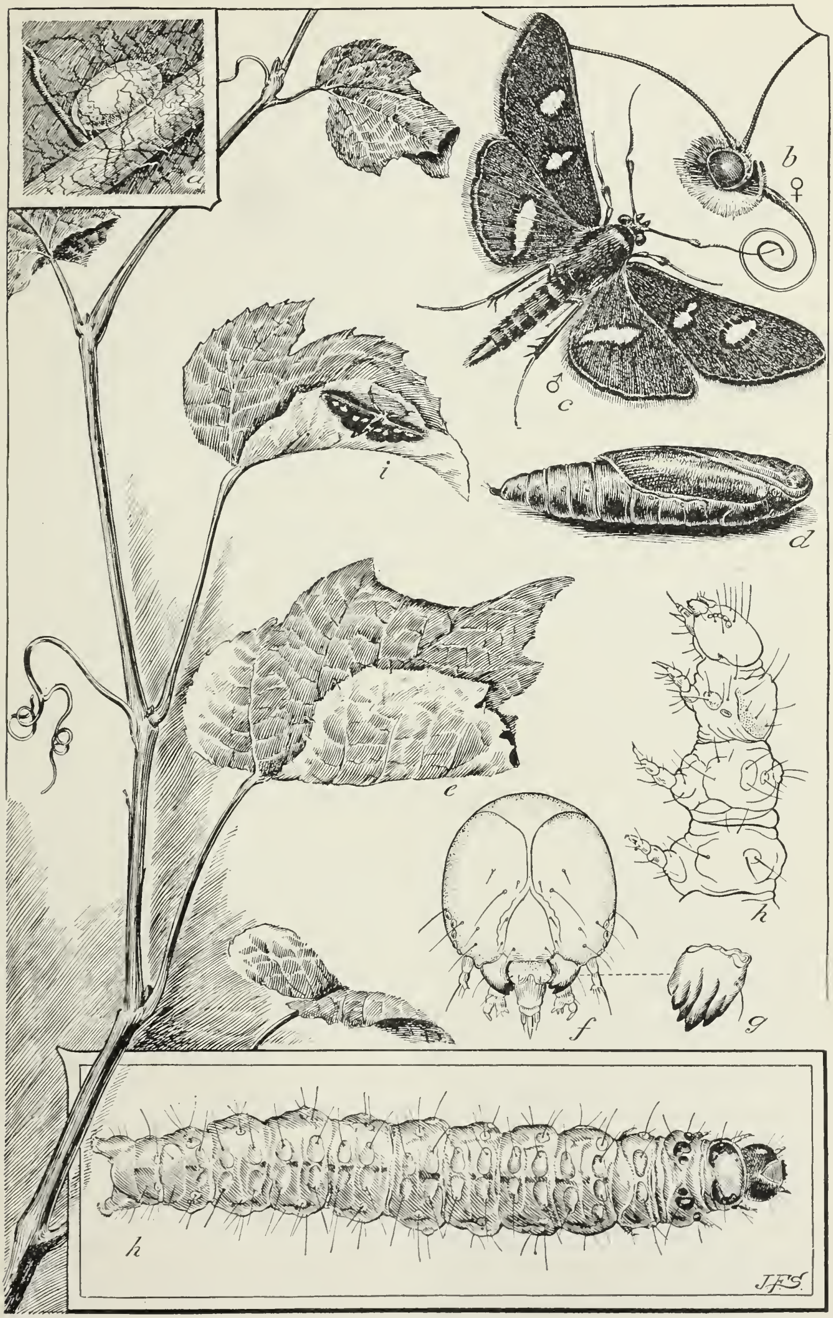


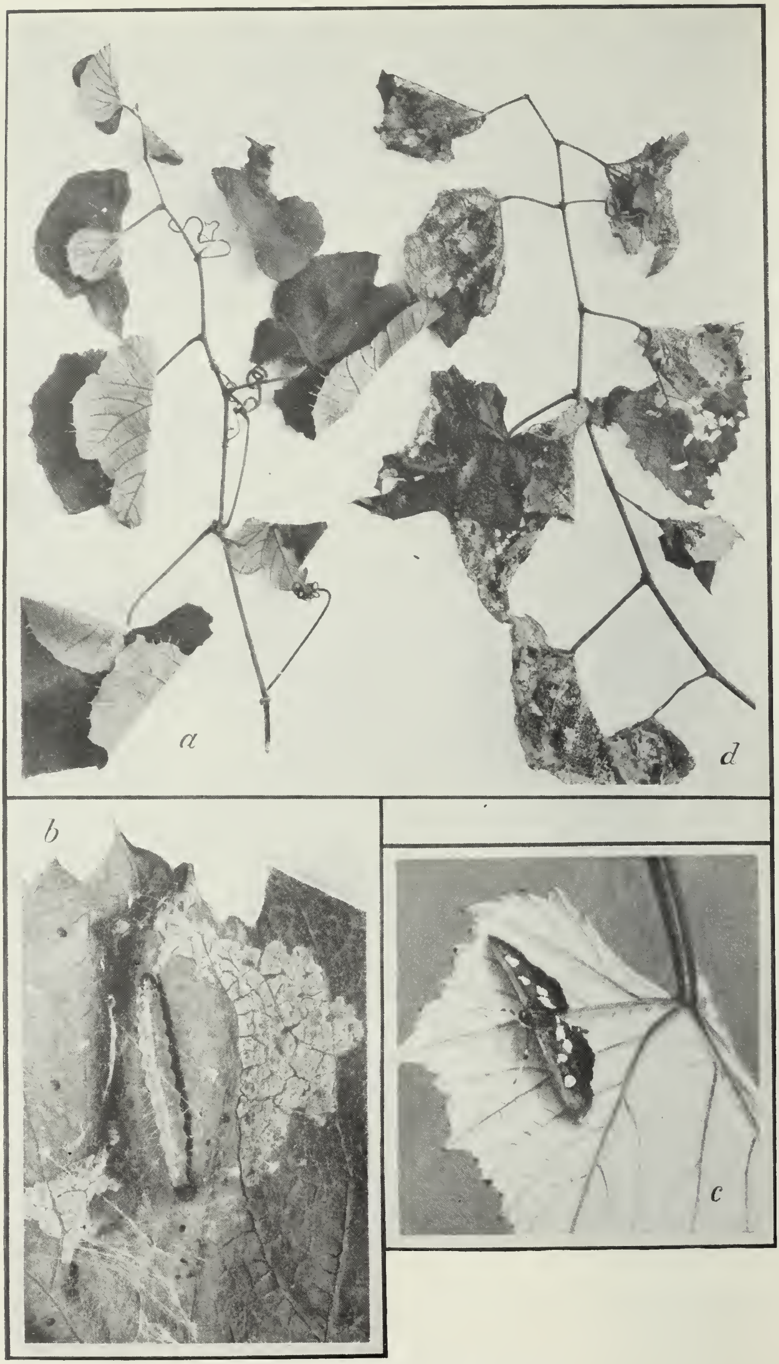
FIG. 1.—Map showing distribution in the United States of the grape leaf-folder, *Desmia funeralis.* (Original.)

Plants other than the grape are fed upon by *Desmia funeralis,* Titus having found it on Virginia creeper (*Parthenocissus quinquefolia* [L.]) near Somerset, Md. He also found two varieties of redbud, *Cercis canadensis* and *Cercis chinensis,* as hosts, in the Department of Agriculture grounds at Washington, D. C.



THE GRAPE LEAF-FOLDER.

Life history of the grape leaf-folder (*Desmia funeralis*): *a*, Egg; *b*, head of adult female, side view; *c*, adult male; *d*, pupa; *e*, folded leaf making a retreat for larva; *f*, enlarged head of larva showing mouth parts, frontal view; *g*, enlarged mandible with which larva eats the tissues of the leaf; *h*, *h*, dorsal view of larva, and head and thorax of same, side view; *i*, moth, natural size. (Original.)



WORK OF THE GRAPE LEAF-FOLDER.

a, Grape leaves recently folded by larvæ; *b*, folded grape leaf torn open to show full-grown larva within (from life); *c*, adult on grape leaf (from life); *d*, effect on grape leaves of attack by larvæ. *a*, *b*, Reduced; *c*, *d*, somewhat enlarged. (Original.)

EXTENT AND CHARACTER OF THE INJURY.

During most years in a few localities throughout its range of distribution, this insect is quite abundant and the cause of important damage to the vine by the destruction of the foliage at a time when this is needed to ripen the fruit properly. During occasional years it may become excessively abundant and destructive, as has been the case in the environs of Washington, D. C., during the past three or four years.

The grape leaf-folder gains its title through the injury inflicted by its larvæ upon the foliage. In the experience of the writer, the direct injury is sustained by the foliage alone, although Mr. Fred Johnson has observed the larvæ of the first brood eating the blossoms and young fruit.

The injury to the leaves is very characteristic and may be easily recognized (Pl. I, *e*). As soon as the larva is large enough it folds the leaf, exposing the under surface, the edge being held in place by bands of silk thread (Pl. II, *a;* Pl. III, *a*). It is within the protection of this fold that the larva feeds, skeletonizing the leaf on the upper surface (Pl. III, *b*).

When the larvæ are numerous the injury to the vine becomes very conspicuous, even at a considerable distance, for the light color of the under surface of the folded leaves contrasts strongly with the dark green of the upper side presented normally, giving the vine a patchy appearance. Later in the season the skeletonized leaves dry up (Pl. II, *d*), exposing the fruit to the rays of the sun and, in case of a severe attack, rendering the fruit unmerchantable. The writer has observed such conditions in several vineyards in Fairfax County, Va.

In a young vineyard at Herndon Heights, Va., consisting of several acres of Concords and Niagaras, four-fifths of the foliage was found to have been destroyed. In the immediate vicinity there was an abundance of badly infested "chicken" grapes (*Vitis aestivalis*), which doubtless served to supply the insects to the cultivated vines.

The experience of a grower with the depredations of this pest at Riviera, Tex., is of interest and is presented in the following letter received by the Bureau of Entomology under date of January 15, 1915:

> This insect was much more troublesome here last year than ever before. It appeared in force just as the grapes were beginning to color or ripen, and so thoroughly stripped off the leaves that the grapes could be used only for jelly, or sauce, by cooking them green. I saved most of mine by dusting the vines with Paris green and lime in the early morning while the dew was on the leaves and the wind was calm, but the few others here who raise grapes had no ripe ones to eat or sell. The clusters hanging below the leaves (and usually getting very little dew) caught very little of the poison.

DESCRIPTION OF THE GRAPE LEAF-FOLDER.

ADULT.

The wings of the moth when fully expanded (Pl. I, *c*) measure about nine-tenths of an inch. These are very dark brown in color with an opalescent or silvery reflection, and are bordered with white. The forewings in both sexes have two nearly oval white spots, while on the hind wings of the male there is one spot, which, in the female, may be divided. The body is black, crossed by two white bands in the female and by one band in the male. The male antennæ are thickened or knotted near the middle, while in the female (Pl. I, *b*) they are uniform and thread-like.

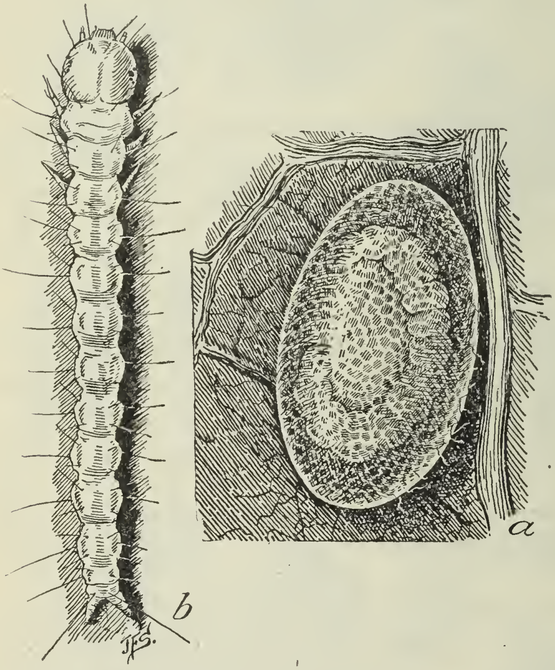


FIG. 2.—*a*, Egg of the grape leaf-folder showing larva just before hatching; *b*, newly hatched larva. Greatly enlarged. (Original.)

THE EGG.

The egg of the grape leaf-folder (fig. 2, *a;* Pl. I, *a*) is elliptical in outline and very minute, measuring about 0.7 mm. in length. Its membranous chorion, or outer covering, presents under high magnification delicate hexagonal markings.

THE LARVA.

The larva, when fully grown (Pl. I, *h;* Pl. II, *b*) is about an inch long, is widest in the middle, and tapers toward either end. It is glossy, translucent yellow-green on the sides and somewhat darker above, with scattered fine yellow hairs on each segment. The head and prothoracic shield (Pl. I, *f*, *h*) are light brown, and there are light-brown spots on the sides of the first two thoracic segments.

THE PUPA.

The average pupa of *Desmia funeralis* is a little over half an inch long (Pl. I, *d*). The light-brown color shown just after pupation soon turns quite dark. The pupa tapers characteristically toward the posterior end, where an 8-hooked cremaster is located.

LIFE HISTORY AND HABITS.

The moths of the grape leaf-folder issued in greatest numbers during the early part of May, from pupæ overwintered in jars in the out-of-door rearing shelter at Washington, D. C. This maximum-emergence date will vary, of course, with different localities, owing to variation in humidity and temperature. Moths were obtained over a much longer period, including the latter part of April, all of May, and most of June.

About 60 minutes is consumed by the insect in emerging from the pupal skin, the operation commencing with a circular abrasion at the head end. The number of females to issue was greater than the number of males by approximately seven to one. Numerous moths, both males and females, were confined in jars for several days and fed on honey and water, but at no time was mating or oviposition observed.

The adults when disturbed fly rather quickly, but as a rule they are to be found at rest on the underside of the leaves (Pl. I, *i;* Pl. II, *c*). The eggs are usually deposited singly on the underside of the leaf (Pl. I, *a*) along the midrib or other veins, or in the angles formed by the branching of the veins. The writer has found eggs scattered over the grape canes, as has been recorded, and the finding of them on the leaves has been corroborated by other observers.

The young larvæ, about one thirty-second of an inch in length (fig. 2, *b*), emerge from the eggs in 8 or 10 days, and as they are unable at this time to fold the leaves, search out a sheltered place among the foliage, or even crawl into the folded shelter made by an older larva, where they commence feeding upon the upper epidermis of the leaf.

During its life the larva molts six times, the thoracic markings becoming darker with each molt. During the periods of three or four days between molts the larva feeds almost continuously, though it is especially active at night.

When about two weeks old the larva makes a small fold in the leaf. It commences the operation by spinning strands of silk from side to side, across a portion of the leaf near the edge, each successive silken strand being shortened until the edge of the leaf is gradually drawn over and fastened with shorter bands of silk. It has been thought by some investigators that among the leaf-tying and leaf-rolling larvæ the folding and fastening of the leaf is not so much the product of actual strength exerted by the immature larva, but is the result of solidification of the newly-produced silken strands in drying. Within this shelter the larva spins a further protection, composed of many recrossed strands of silk (fig. 3). If its shelter is torn open, the larva wriggles violently and usually falls to the ground.

The attacks of a larva are not necessarily confined to a single leaf. In rearing experiments conducted in jars two leaves usually constituted the food of a single larva throughout its life. On the other hand, a single large leaf may be the object of attack of more than one larva, seven having been counted under field conditions.

In the latitude of Washington, and perhaps in most of the Northern States, there are two generations of the grape leaf-folder each year. In the Southern States it is thought that there may be three or more generations annually.

The majority of first-brood larvæ pupate during July, the average length of time passed in the larval stage being about four weeks. The full-grown larvæ leave their shelters and drop to the ground, where they transform among fallen leaves, trash, etc. In exceptional cases a larva may web several leaves together on the grapevine and pupate within this shelter, or it may even pupate within the folded leaf where it has fed.

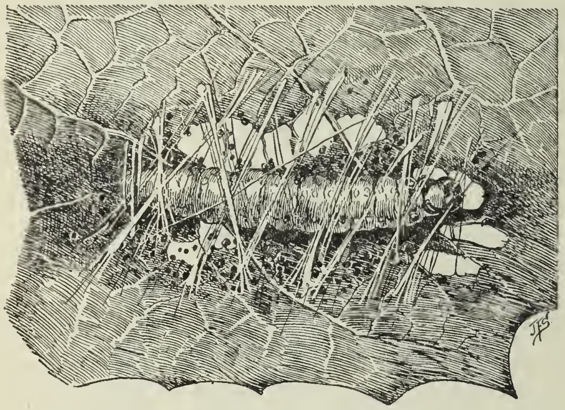


FIG. 3.—Larva of grape leaf-folder under its web on grape leaf, which has been spread open. Much enlarged. (Original.)

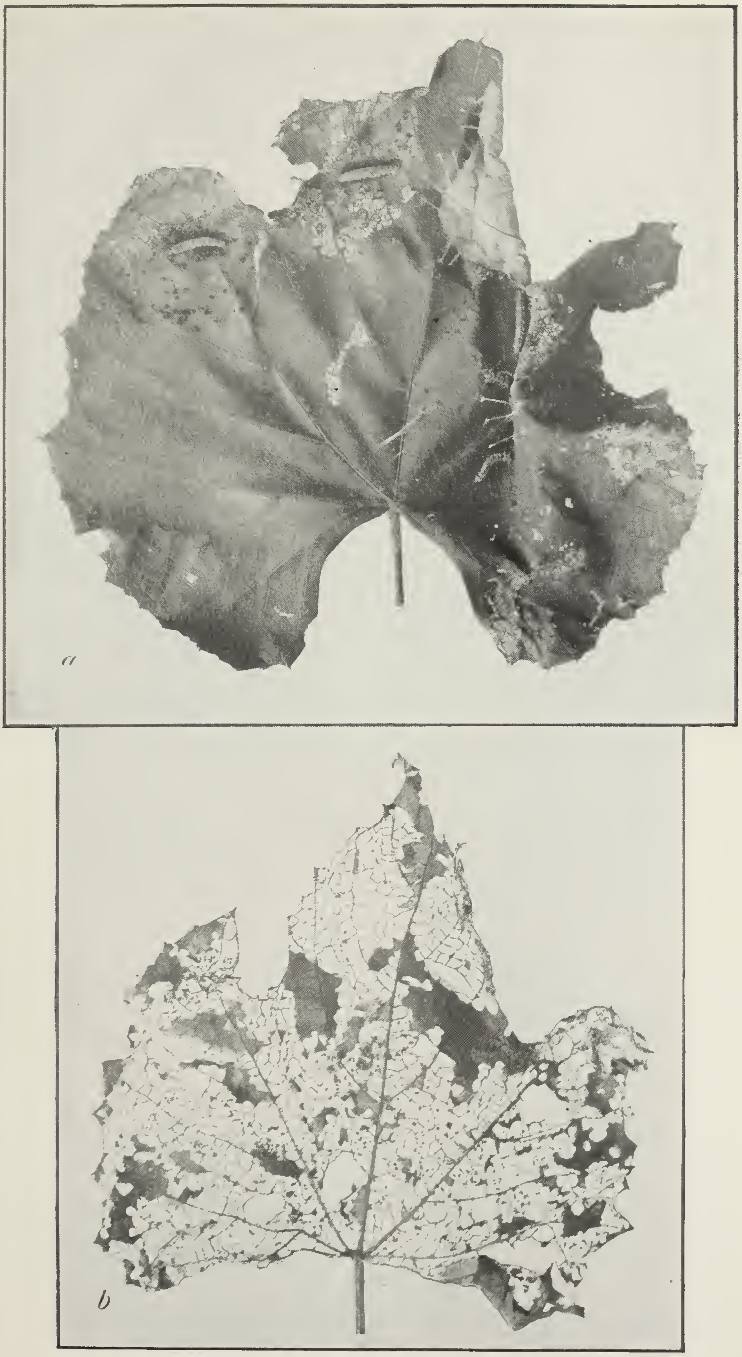
During the latter part of July and throughout August the moths are again flying and depositing eggs, from which will hatch the larvæ of the second brood.

Compared to the number of larvæ that appear in the second brood, those of the first are quite insignificant, and it is through this great increase in numbers that the injury becomes serious in late summer and fall.

These larvæ of the second brood begin to pupate in September in the latitude of Washington, and by the middle of October few, if any, are to be found in the leaves. The pupæ of this brood are also to be found among the dead leaves on the ground, and it is in this stage that they pass the winter.

NATURAL ENEMIES.

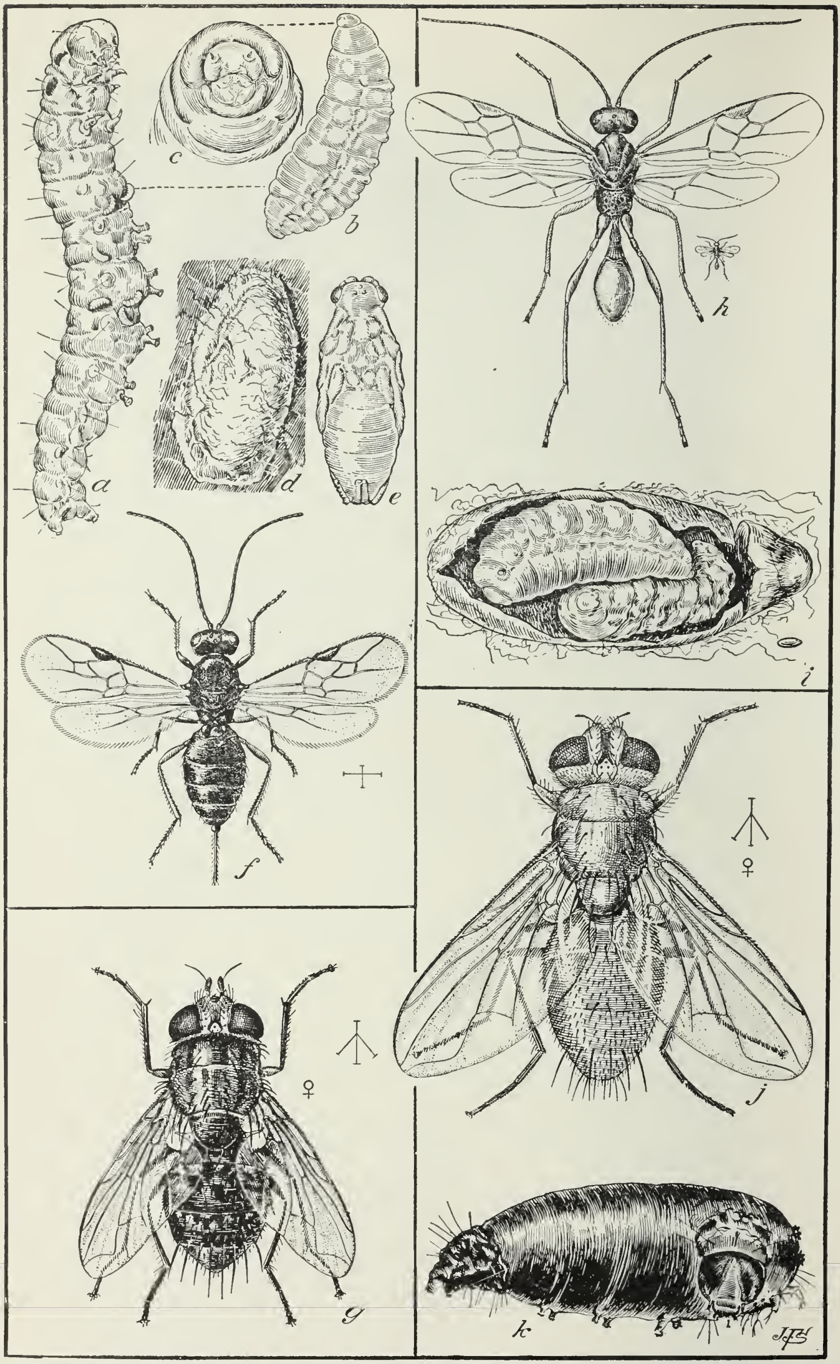
The larvæ and pupæ of *Desmia funeralis* are preyed upon by a number of hymenopterous and dipterous parasites. These natural enemies help materially in keeping down the numbers of the pest, and are, together with other factors, responsible for the greatly diminished numbers of the overwintered pupæ, and consequently of the first brood of larvæ in the spring.



WORK OF THE GRAPE LEAF-FOLDER.

a, Grape leaf attacked by leaf-folder, several folds being torn open to show larvæ; *b*, grape leaf skeletonized by larvæ. (Original.)

PLATE IV.



PARASITES OF THE GRAPE LEAF-FOLDER.

a, Newly hatched larvæ of *Habrobracon johannseni* feeding on larva of grape leaf-folder; *b*, Habrobracon larva, more enlarged; *c*, head of Habrobracon larva, still more enlarged, showing rudimentary antennæ; *d*, Habrobracon cocoon on portion of grape leaf; *e*, ventral view of pupa of Habrobracon; *f*, adult Habrobracon; *g*, *Exorista pyste;* *h*, *Meteorus dimidiatus* (natural size at right); *i*, *Perilampus platygaster*, an internal hyperparasite attacking Meteorus larvæ in Meteorus cocoon; *j*, *Leskiomima tenera*, adult; *k*, puparium of Leskiomima, showing remains of chitinized parts of grape leaf-folder. Much enlarged. (Original.)

Following is a list of parasites of *Desmia funeralis* reared by the writer:

HYMENOPTERA.

Apanteles canarsiae Ashm.
Habrobracon johannseni Vier.
Meteorus dimidiatus Cress.
Pardianlomella ibseni Gir.
Trichistus pygmaeus Cress.
Mesochorus scitulus Cress.
Gemocerus sp.

DIPTERA.

Tachinophyto variabilis Coq.
Exorista pyste Walk.
Leskiomima tenera Wied (Pl. IV, *j*, *k*).

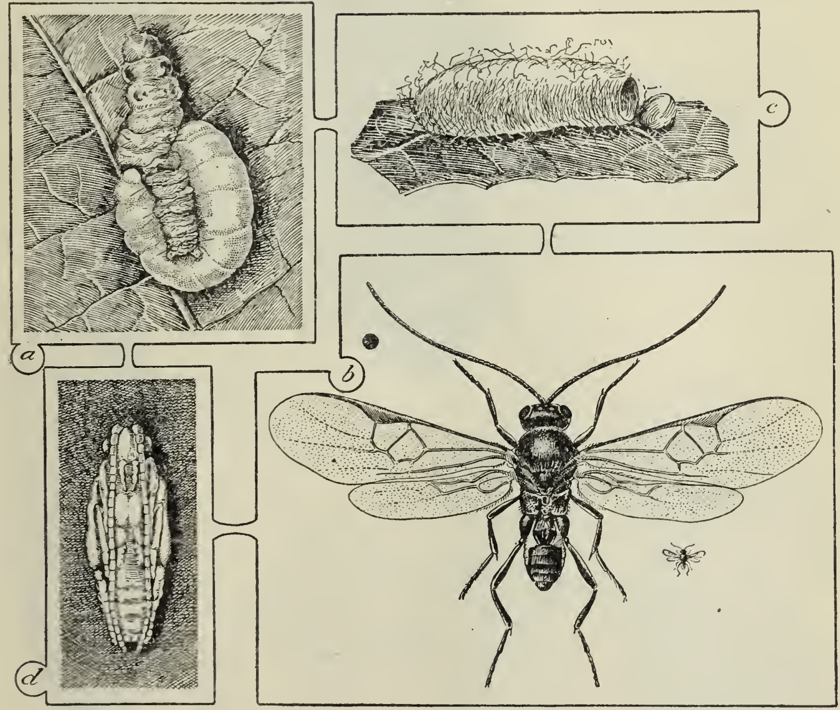


FIG. 4.—*Apanteles canarsiae*, a parasite of the grape leaf-folder: *a*, Apanteles larva feeding on grape leaf-folder larva; *b*, adult Apanteles (natural size at right below); *c*, cocoon of same; *d*, pupa of same. Much enlarged. (Original.)

The following notes were made on the life histories of several of the foregoing species during the course of the study.

Several individuals of *Apanteles canarsiae* Ashm. (fig. 4) were found in considerable numbers. Their small white cocoons were quite abundantly scattered over the larval webs of Desmia during the latter part of August and the first of September. The minute, sluglike larvæ of the parasite feed externally, a single individual completely consuming the soft parts of its host. When fully grown the larva crawls some distance from the remains of its host, and within an hour has constructed its cocoon, within which pupation takes place (fig. 4, *c*). In about five days the adult Apantales issues.

Meteorus dimidiatus Cress. (Pl. IV, *h*) was found reasonably abundant in one locality in Virginia. It attacks the Desmia larvæ during the early autumn. When full grown the larva spins an oval brownish cocoon 4 or 5 mm. long, which it fastens down to the grape leaf with silk threads. Numerous adults were reared during September from cocoons collected on grape leaves. This species is itself parasitized, *Perilampus platygaster* Say having been found attacking it in both the larval and pupal stages (fig. 5; Pl. IV, *i*).

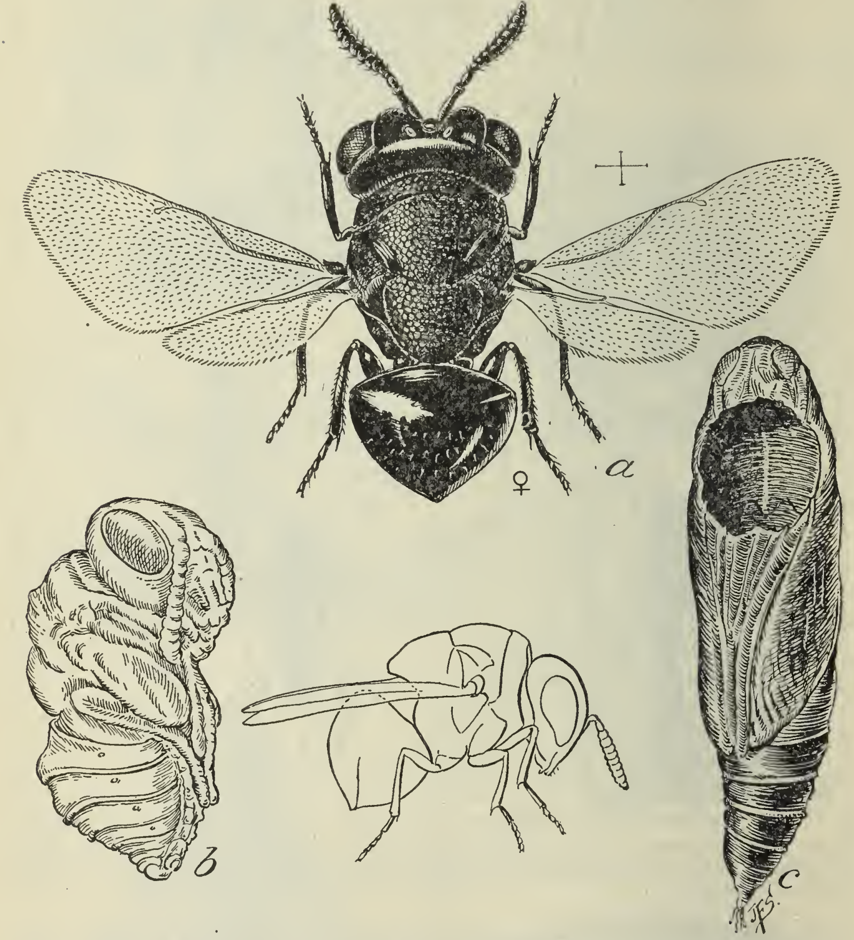


Fig. 5.—*Perilampus platygaster*, a parasite of *Meteorus dimidiatus*, which in turn is a parasite of the grape leaf-folder: *a*, Adult female (profile view below); *b*, pupa of same; *c*, pupa case of grape leaf-folder from which adult Perilampus issued. Greatly enlarged. (Original.)

On September 27 several eggs of a new species of eulophid, *Pardianlomella ibseni* Gir. (fig. 6) were found scattered over the web and body

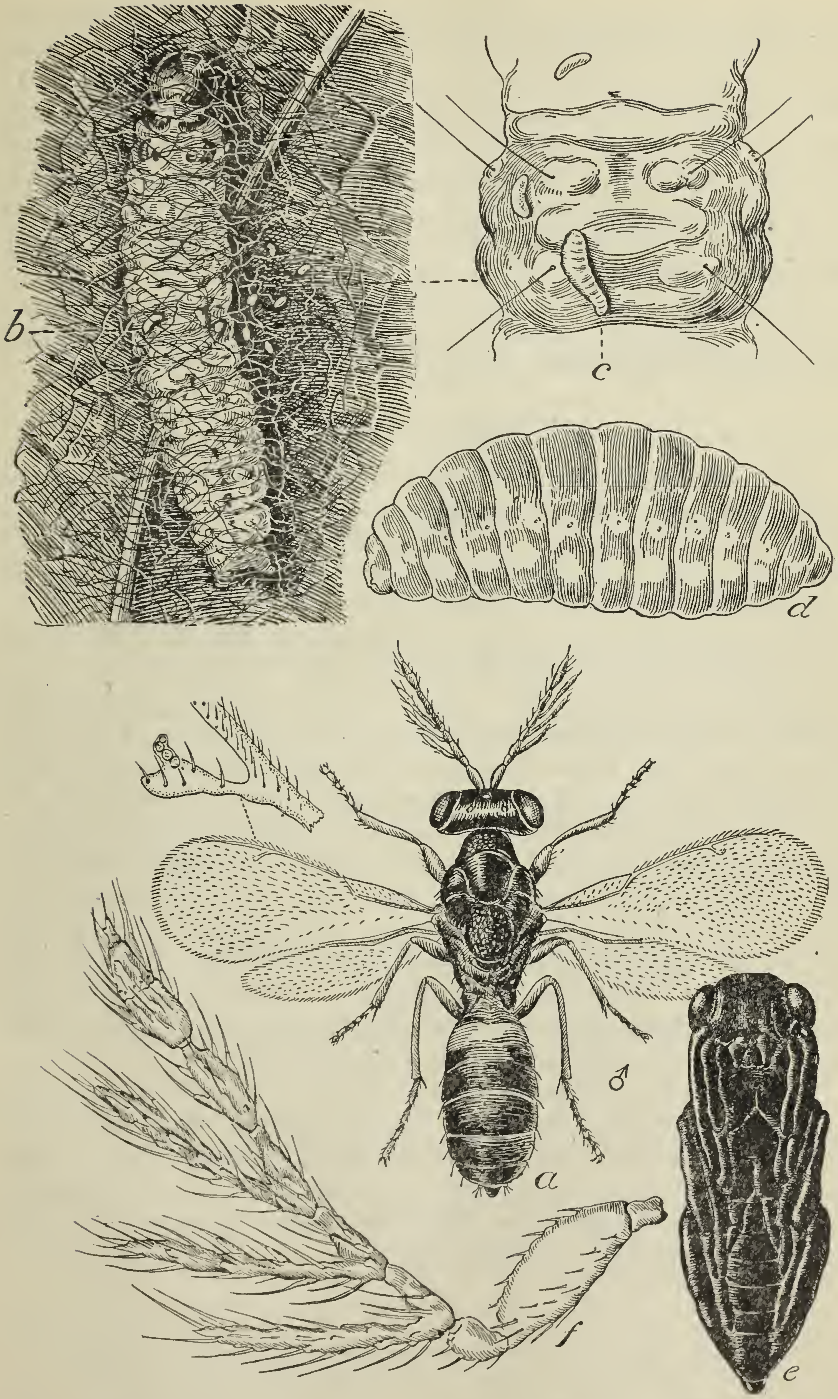


Fig. 6.—*Pardianlomella ibseni,* a parasite of the grape leaf-folder: *a*, Adult male; *b*, eggs of *Pardianlomella ibseni* on leaf-folder larva; *c*, egg and newly hatched feeding larva on segment of leaf-folder larva; *d*, larva of Pardianlomella, full grown; *e*, pupa of same; *f*, antenna of adult, highly magnified. All much enlarged. (Original.)

of a larva of the grape leaf-folder. These eggs hatched the following day, and the active little parasites greedily attacked their host, feeding externally, their mouth parts embedded in the soft tissues. In five days they left the remains and pupated. The pupæ at first were milk white, but later turned black. These pupæ overwintered in jars, and on May 30 of the following spring the adults issued (fig. 4, *d*).

Habrobracon johannseni Vier. (Pl. IV, *a–f*), a new species of braconid, was found widely distributed. It feeds externally upon the Desmia larvæ.

The fly parasites of the grape leaf-folder were taken only in small numbers. The most abundant of the three species was the tachinid *Exorista pyste* Walker (Pl. IV, *g*).

METHODS OF CONTROL.

Vineyards regularly sprayed with arsenicals for the control of the grape rootworm, grape-berry moth, etc., will be practically free from injury by the grape leaf-folder. The insect is especially likely to cause injury in small vineyards not regularly sprayed and to grapes grown in arbors in backyards and similar places.

Where the insect has been troublesome in previous years, the vines should be well sprayed with arsenate of lead at the rate of 2 pounds of the paste or 1 pound of the powdered article to 50 gallons of water, shortly after the blossoms have fallen. One treatment at this time, if thoroughly made, should destroy the caterpillars of the first brood so effectually that injury by second-brood larvæ would be of little importance. If the caterpillars continue troublesome, however, additional applications should be made. Arsenicals are usually applied to grapes in fungicides, as in Bordeaux mixture for the control of fungous diseases. Information on the general subject of spraying grapes is contained in Farmers' Bulletin 284, United States Department of Agriculture. For small spraying operations, as in back yards, a very simple spraying outfit may be employed, such as a bucket pump or knapsack pump.

Where it is impracticable to spray the vines, it will be decidedly advantageous to go thoroughly over the plants when the folded leaves are in evidence and crush the larvæ by hand. As an additional method of reducing injury it is advisable to rake together and burn fallen foliage in the fall, since the insect passes the winter in the pupal condition in these leaves.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 420

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

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COOLING HOT-BOTTLED PASTEURIZED MILK BY FORCED AIR.

By S. Henry Ayers, John T. Bowen, and W. T. Johnson, Jr.,
Dairy Division, Bureau of Animal Industry.

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INTRODUCTION.

Since 1912 the process of cooling hot bottled milk by means of forced-air draft has been studied in the Dairy Division of the Bureau of Animal Industry. The first experiments, which were conducted on a laboratory scale, indicated that forced-air circulation might be successfully used for cooling hot pasteurized milk in bottles. The results of that investigation[1] indicate the probable means by which the method could be used on a commercial scale. It was realized that laboratory and commercial conditions are essentially different, and in consequence cooling experiments on a 30-crate basis were started in 1913. In this paper we shall give the results of this work. As additional information, some data on the reverse process—the heating of cold bottled milk by means of circulated hot air—will also be given.

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[1] Ayers, S. Henry, and Johnson, W. T., jr., Pasteurizing Milk in Bottles and Bottling Hot Milk Pasteurized in Bulk. Bulletin 240, U. S. Department of Agriculture. Also in Jour. of Infec. Dis., vol. 14, No. 2, March, 1914, pp. 217-241.

DESCRIPTION OF EXPERIMENTAL APPARATUS.

In order to conduct cooling experiments with forced-air circulation on a small scale, an insulated box 10 feet 6 inches high, 5 feet wide, and 4 feet 8½ inches deep was constructed. The box was insulated by a 4-inch wall of sawdust, and inside it was built a platform 2 feet 2 inches from the floor, composed of movable sections each the size of the bottom of a milk-bottle crate. The plan of this box, together with the blower set and arrangement of piping, is shown in figure 1.

The blower set consisted of a steel-blade fan of a capacity of 2,000 cubic feet a minute at normal speed, and was operated by a 125-volt direct-current, shunt-wound, open-type, variable-speed motor of 1½ horsepower. The blower was connected to the box by pipes of galvanized iron of 14-inch diameter, which were so arranged that air could be forced in at the bottom of the box and out at the top, or the reverse; that is, in at the top and out at the bottom. This was made possible by two inlet and outlet pipes connected with the box and controlled by a system of dampers.

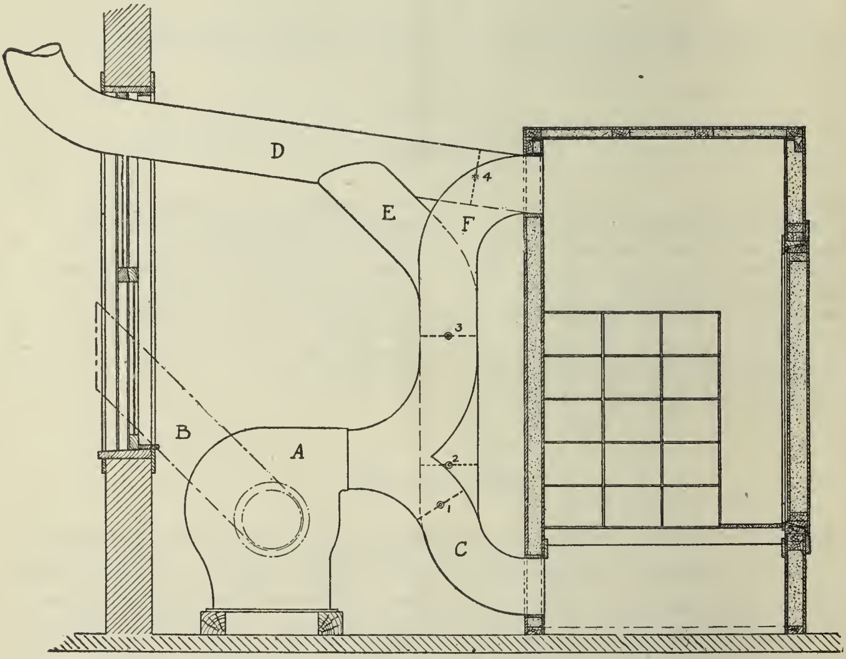

FIG. 1.—General arrangement of cooling apparatus.

Most of our experiments were conducted during the winter months; consequently the outside air was sufficiently cold for the cooling process. As may be seen in the figure, the blower drew outside air through pipe B and forced it into the cooling box.

Thirty crates of bottles, stacked in six piles each five crates high inside the box, were cooled at one time. Before the crates were stacked on the platform the movable sections were removed, so that the space under the crates was open and the rest of the platform closed. By this arrangement it was possible to force all the air directly through the crates of bottles.

When air was forced up through the crates the operation was as follows: Air was drawn by blower A through pipe B from the outside of the building and forced through pipe C into the bottom of the cooling box. From that point it was forced up through the piles of crates and passed out from the top through pipe D. In this case damper No. 1 in pipe C was open and damper No. 3 in pipe F was closed, while damper No. 2 in pipe E was closed and damper No. 4 in pipe D was open.

When air was to be forced down through the crates, and consequently had to enter at the top of the box, it was necessary simply to change the dampers in the pipes. To force air in at the top through pipe E, damper No. 1 was closed and No. 3 opened; in the outlet pipes damper No. 2 was opened and No. 4 closed. This system of pipes and dampers would not be necessary for cooling milk on a commercial scale, but was necessary for experimental purposes.

DESCRIPTION OF INSTRUMENTS AND METHOD OF RECORDING DATA.

Temperatures [1] were determined with copper-constantin thermo elements made from No. 30 wire, tested to the required degree of accuracy for thermoelectric homogeneity. Junctions were soldered, wound with silk thread, and inclosed in thin glass tubes. Where leads were exposed to steam or air blast the double-silk insulation was protected by being incased in black-rubber tubing. Each element was composed of two pairs of couples in series. A calibration curve for each element was constructed from the potential given when the cold junction was immersed in a thermos bottle containing crushed ice, and the hot junction was immersed (1) in melting ice, (2) in a fusion of recrystallized sodium sulphate (Richard's point), and (3) in steam at known barometric pressure. In each case the temperature was also taken with a thermometer calibrated by the Bureau of Standards. From the calibrations so obtained deviation curves were constructed and used with Adams's [2] table.

Potentials were measured with a Leeds and Northrup potentiometer and galvanometer. The potentiometer was calibrated by the Bureau of Standards. A Weston cell certified by that bureau furnished the known potential. A switch, essentially the same as that described by White,[1] was used to correct for parasitic electromotive forces.

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[1] We are greatly indebted to Dr. W. M. Clark, of the Dairy Division, for preparing, describing, and operating a system for temperature measurements by means of thermocouples.

[2] Adams, L. H. Journal of American Chemical Society, 36, p. 65, 1914.

In the set-up the hot junction of each element was placed where desired and the cold one packed in crushed ice within a thermos bottle. The terminals were led to mercury pools in a block of paraffined wood protected from air currents. Connection with the potentiometer was made through copper leads whose bared and amalgamated ends could be dipped in the successive pairs of mercury pools. In this way any element could be quickly and easily brought into circuit.

Differences of one microvolt could be detected by the system. This corresponds to approximately 0.018° F. (0.01° C.). The experimental errors incident to rapid readings resulted in an accuracy of about 0.09° F. (0.05° C.).

In determining the difference in temperature between the top and bottom of a bottle a differential thermo element was used; this consisted of two pairs of copper-constantin couples in a thin glass tube. The hot and cold junctions were placed so that one would be about one-half inch above the bottom and the other just beneath the surface of the liquid when cool. This differential couple was not calibrated, and its design was not all that could be desired, but it doubtless was sufficiently accurate to furnish a fairly good measure of the differences in temperature between the top and bottom layers. In this connection it may be noted that the thermometers used in this work are numbered from 1 to 10, which numbers are used to identify them with the curves in the drawings showing the results of the various experiments.

Air measurements were taken with a Taylor-Pitot tube placed in the center of the straight part of the discharge pipe from the box, about 4 feet from the nearest bend. The tube was arranged to give both the impact and static pressure, their difference, or the velocity head, being indicated on a graduated water column. Only one tube, situated in the center of the pipe, was used. The average velocity head across the entire section of the pipe was determined by multiplying this center reading by the factor 0.91.

The velocities obtained with the Pitot tube were checked with an anemometer which had been calibrated by the Bureau of Standards. The anemometer was moved across the end of the outlet pipe in such a way as to give what was considered an average reading. As the temperature of the air in the outlet pipe from the box was, of course, higher than that of the incoming air, the volumes were corrected in the ratio of their absolute temperatures to give the inlet volume.

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[1] White, Walter P. Journal of American Chemical Society, 36, p. 1856, 1914.

The corrected anemometer readings were in every case higher by approximately 10 per cent than those obtained with the Pitot tube.

The wet-bulb and the dry-bulb temperatures were taken by a sling psychrometer. The barometer was read during each test, and the weight of air per cubic foot determined from the barometer and the wet-bulb and the dry-bulb readings.

Readings of air velocities were also taken with an anemometer over the tops of the crates. These readings, taken at different places over the stacks, were practically the same and averaged 182 feet a minute over the quart crates and 156 over the pints. It is very important that a practically uniform velocity of air be maintained throughout the stack in order to cool all bottles at the same rate. Thirty crates, stacked 5 high, were used in all experiments, 15 for quart bottles and 15 for pints. Reading of volts, amperes, and speed of motor were also taken during each experiment.

RELATIVE RATE OF COOLING OF MILK AND WATER.

As the average specific heat of whole milk is less than that of water, it may be expected to cool faster under the same conditions. This, however, is not the case when the cooling is done in bulk, such as when in bottles or cans, as is plainly shown in figure 2. These curves are plotted from temperature readings taken in a quart bottle of milk and a quart bottle of water, subjected to the same conditions of air velocity, air temperature, location of thermometers in bottles, etc.

It will be seen that the curve representing the rate of cooling the milk is of a uniformly higher temperature than the similar curve for water.

On account of the small variation in the relative rate of the cooling of milk and water it was considered advisable to use water in these experiments, as it was more easily obtained and handled. Bottles of milk, however, were distributed throughout the crates, in selected places, and in these bottles, as well as in those containing water, similarly placed, the temperature readings were taken.

RELATIVE RATE OF COOLING WITH STILL AIR AND FORCED AIR.

In order to obtain data to compare the rate of cooling bottles and cans containing milk when exposed to still air and to moving air, pint and quart bottles, and 10-gallon cans of milk were placed in a refrigerated room, the constant temperature of which was held at approximately 40° F. (4.4° C.). The initial temperature of the milk was about the same in all instances. The results are seen in figures 3, 4, and 5. Figures 3 and 4 show the relative drop in temperature between pints and quarts, respectively, when exposed to still air and to moving air, and figure 5 shows similar results for the 10-gallon cans.

The bottles placed in still air were cooled by natural circulation brought about by the difference in temperature between the comparatively warm air in contact with the outer surface of the bottles and that at a distance. As the air in contact with a hot surface, such as that of the bottles containing milk, becomes heated, it rises and its place is taken by cold air; hence, the rate of circulation of the air depends upon the difference in weight of the respective columns of warm and cold air. As this difference in weight is very slight, the circulation is naturally slow, and hence a slow rate of cooling follows.

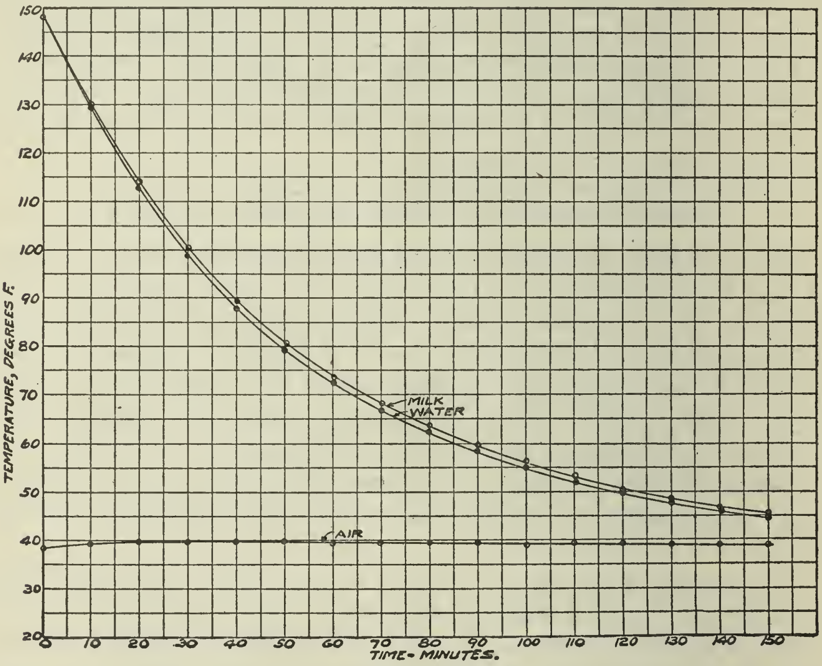

FIG. 2.—Cooling of milk and water by forced air.—Difference in the rate of cooling of milk and water when exposed to an air blast. Quart bottles.

In the case of forced circulation of air, however, the film or sleeve of hot air surrounding the vessel is broken up, and a large volume of cold air is brought into direct contact with the outer surface of the container; the cooling therefore goes on very much faster. The forced circulation of the air in these experiments was made by a 16-inch electric fan, which produced over the bottles an air velocity of approximately 1,250 feet a minute, measured by an anemometer which had just been calibrated by the Bureau of Standards.

It will be noted by reference to figure 3 that it required 4½ hours to reduce the temperature of the milk in the pint bottles when placed in still air from 142° to 50° F. (61.1° to 10° C.) with a practically constant temperature of 40° F. (4.4° C.) inside the room. When the air was circulated, however, this drop in temperature was obtained in 1 hour and 27 minutes, or in approximately one-third the time required for an equal drop in temperature when the bottles were exposed to still air.

Referring to the two similar curves in figure 4, showing the results obtained with quart bottles of milk under the same conditions, it will be noted that the relative rate of cooling between the bottles exposed to still air and moving air is the same as that for pint bottles, except that the quart bottles are uniformly higher in temperature than the pints for the same period of cooling.

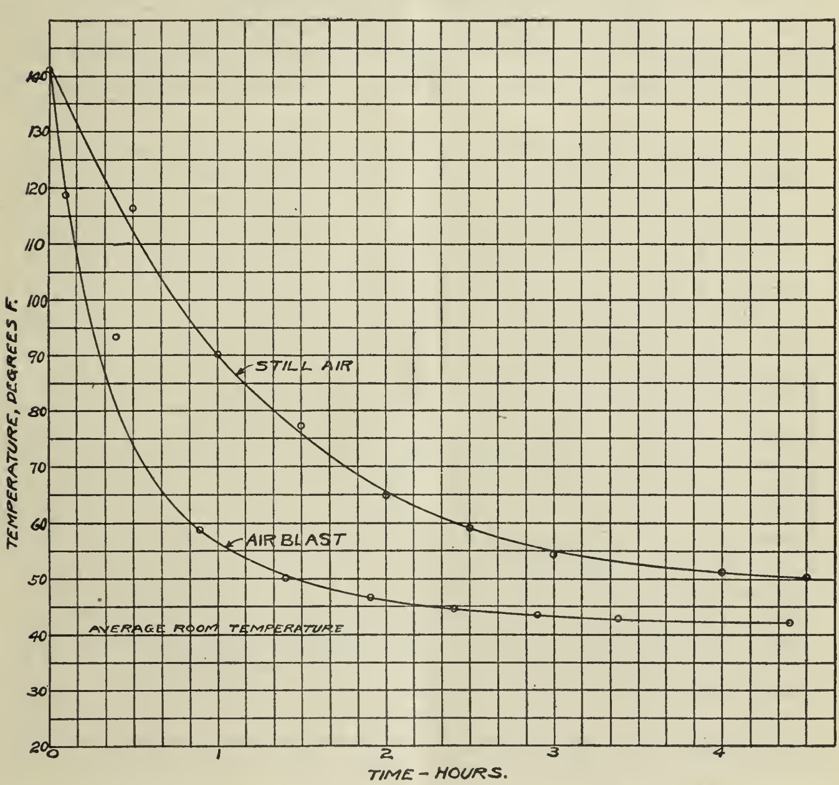

FIG. 3.—Cooling in still air compared with forced air.—Relative drop in temperature between pint bottles of milk cooled in still and moving air. Velocity of moving air 1,250 feet per minute.

The curves in figure 5 show the relative drop in temperature of the milk contained in 10-gallon cans when placed in still air and in moving air. The air blast in this case was also furnished by a 16-inch electric fan which gave an air velocity of 1,250 feet a minute. The conditions were practically the same as those for the pints and quarts, except that the temperature inside the room averaged 42° F. (5.5° C.), or 2 degrees higher. The temperature of the milk contained in the 10-gallon can, placed in still air, was reduced to only

90° F. (32.2° C.) in 6½ hours. A corresponding drop in temperature, however, was obtained with moving air in 2 hours and 15 minutes. The relative rate of cooling between the milk contained in the two cans was in the ratio of about 1 to 3, or, the milk contained in the can which was subjected to an air blast required only about one-third the time to drop in temperature from 147° to 90° F. (63.9° to 32.2° C.) as did the can placed in still air.

Under the foregoing conditions the relative rate of cooling, then, seems to be about the same in vessels of equal size and shape. The time required, however, for cooling through a given range, other things being equal, depends on the size of the containing vessel. In fact, it is believed that in commercial practice quart bottles are about the limiting size of containers that should be used. Our experiments with forced-air cooling, therefore, deal only with pint and quart bottles of hot milk or water.

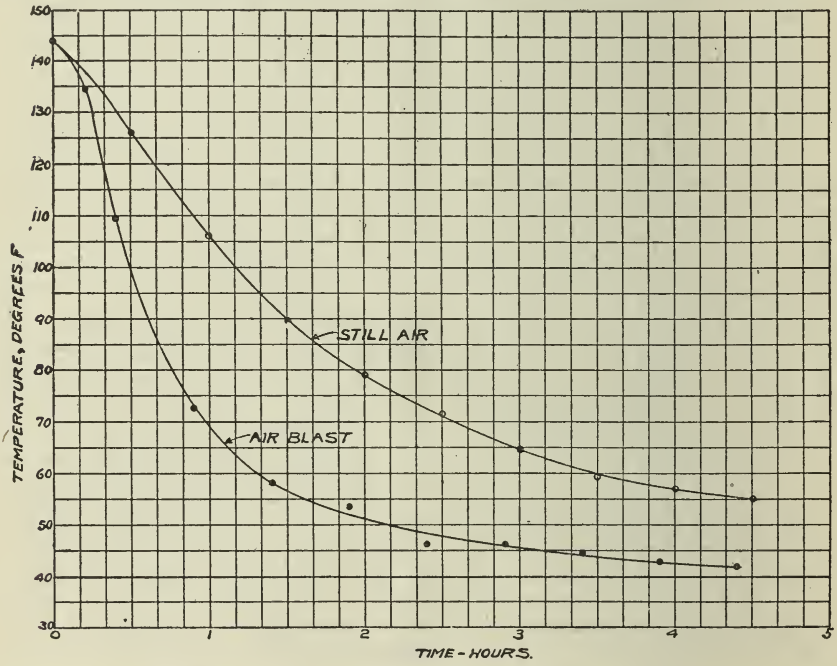

FIG. 4.—Cooling in still air compared with forced air.—Relative drop in temperature between quart bottles of milk cooled in still and moving air. Velocity of moving air 1,250 feet per minute.

In the foregoing experiments with moving air the air was forced in a horizontal direction over the containers. The direction of the air flow, when cooling milk by forced circulation, affects materially the rate of cooling and also the variation in temperatures of bottles at different points in the stack. This feature will be discussed later.

The foregoing experiments serve principally to show that the time required to cool milk to any great extent by natural circulation is too slow for satisfactory operation on a commercial scale, and that with forced-air circulation it is necessary to have small containers, such as quart or pint bottles. In these experiments only a few bottles were cooled by natural circulation; if a large number had been stacked in piles the cooling process would have been even slower.

RESULTS OF COOLING BY MEANS OF FORCED AIR.

BY FORCING THE AIR FROM BOTTOM UPWARD.

The experiments previously described were of a preliminary nature, and we shall now take up the cooling experiments performed on a 30-crate basis.

The cooling effect of cold air when forced through stacks of crates from the bottom is shown by the curves in figures 6 to 9, inclusive.

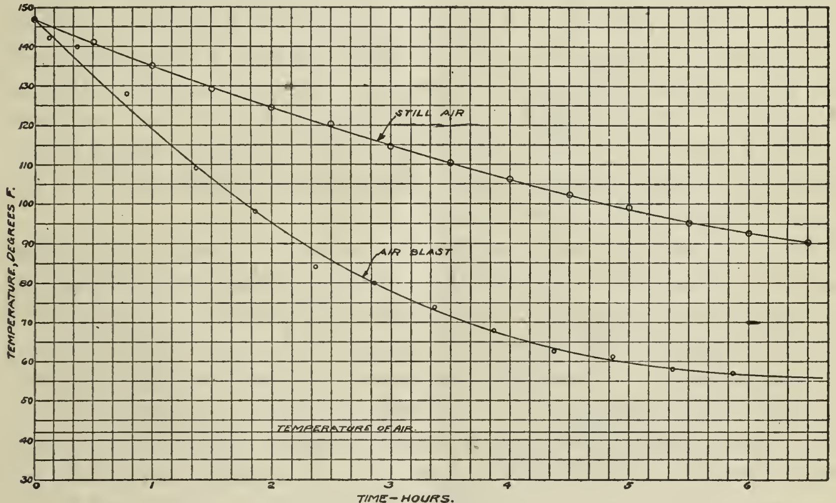

FIG. 5.—Cooling in still air compared with forced air.—Relative rate of cooling of 10-gallon cans of milk when placed in still and in moving air. Velocity of moving air 1,250 feet per minue.

The results, shown graphically by the curves, have been selected on account of some special feature, the discussion of which follows immediately after each set of curves.

All the experiments made with air entering at the bottom and flowing upward and around the bottles show a wide difference in temperature between pint and quart bottles occupying upper and lower positions in the stack, this temperature varying with the height of the particular bottle from the bottom of the stack. The lower bottles, over which the cold air first passed, of course cooled faster than the upper ones, and the rate of cooling decreased rapidly as the distance from the cold-air inlet increased. The temperatures were very accurately determined by means of thermocouples, which have already been described. Several experiments were carried out, using air at different temperatures for cooling purposes.

In figure 6 are shown the results of cooling by air at an average temperature of 67.9° F. (19.9° C.). A complete set of curves is incorporated, principally to show the rate of cooling with air at this high initial temperature. Curves 3 and 4 show the relative rate of cooling between quart bottles of milk and water, respectively, when placed side by side at the bottom of the stack. These curves agree very closely with those in figure 2. Curves 5 and 6 show, respectively, the rate of cooling between pints and quarts placed at the top, or fifth, tier of crates. Curves 3 and 6 are plotted from temperature readings taken in the lower quart of milk and the upper quart of water, respectively. The average difference in temperature between these bottles was 9.8° F. (5.4° C.), while the maximum difference was about 19° F. (10.5° C.). Curves 5 and 6 are practically parallel throughout the range, the curve showing the drop in temperature of the pint remaining throughout about 5 degrees lower than that of the quart. The average difference in temperature between curves 4 and 6, which are plotted from temperature readings taken in the lower and upper quarts of water, respectively, is 10.5° F. (5.8° C.), while the greatest is 20° F. (11.1° C.).

The temperatures indicated by the curves in figure 7 were determined in a pint and a quart bottle at the top of the stack and also one of each kind at the bottom. The temperature of the lower quart and pint, as shown by curves 3 and 4, respectively, drops below that of the outgoing air. It should be remembered, however, that the temperature of the outgoing air was taken at the point where it left the box; hence, the temperature of the air passing over the bottles was lower than that indicated by the curves. Toward the end of the run the temperature of the lower pint was reduced below that of the incoming air. This was caused by the temperature of the outside air rising so rapidly that that of the lower pint, which had been cooled, had not had sufficient time to adjust itself to the rising temperature of the outside air. The average difference between the lower pint and the upper quart, curves 4 and 5, was about 25° F. (13.9° C.), while the maximum difference in temperature was about 43° F. (23.9° C.). This difference becomes more marked when the temperature of the outside air is lower, consequently, when blowing air up through the crates there is great danger of the top crates not being cooled properly, while on the other hand the milk in the lower crates may be frozen, provided the initial temperature of the incoming air is below the freezing point. By comparing temperature curves 3 and 6, lower quart and upper pint, respectively, it will be noted that the temperatures in the two bottles were much nearer each other. The maximum difference was about 12° F. (6.7° C.), but the average was

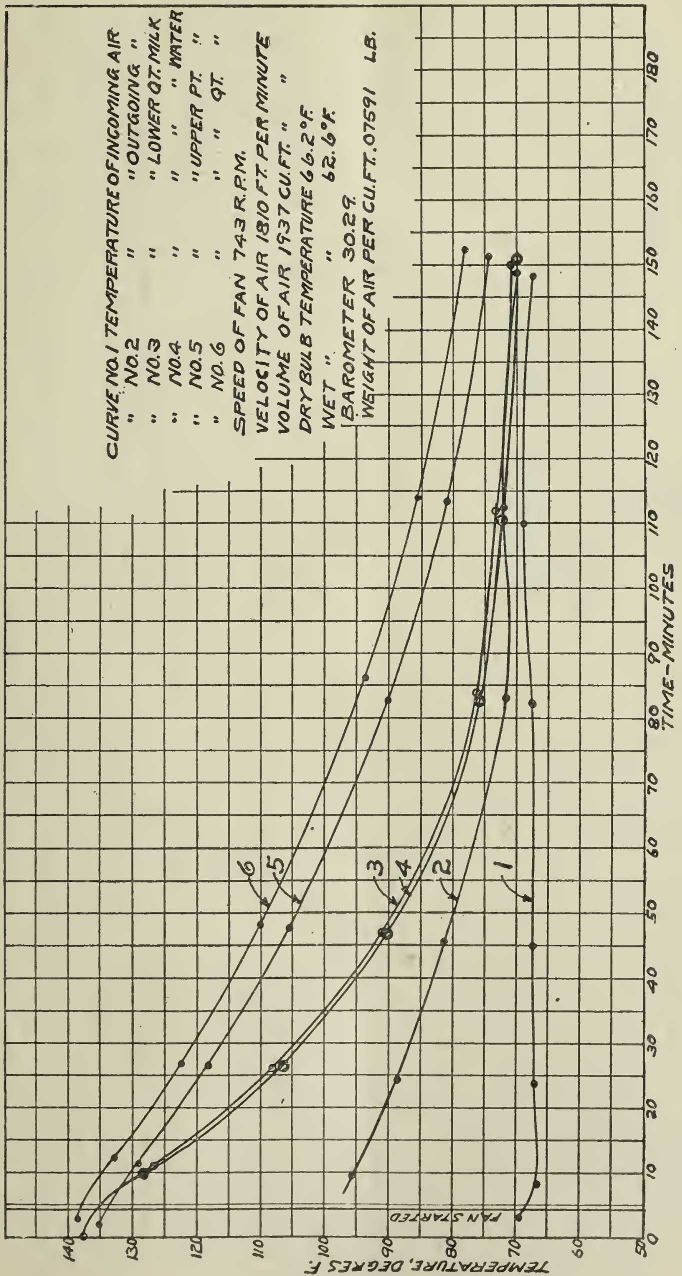

FIG. 6.—Cooling by forced air from bottom upward.—Relative drop in temperature of bottles of milk and water at different positions in stack.

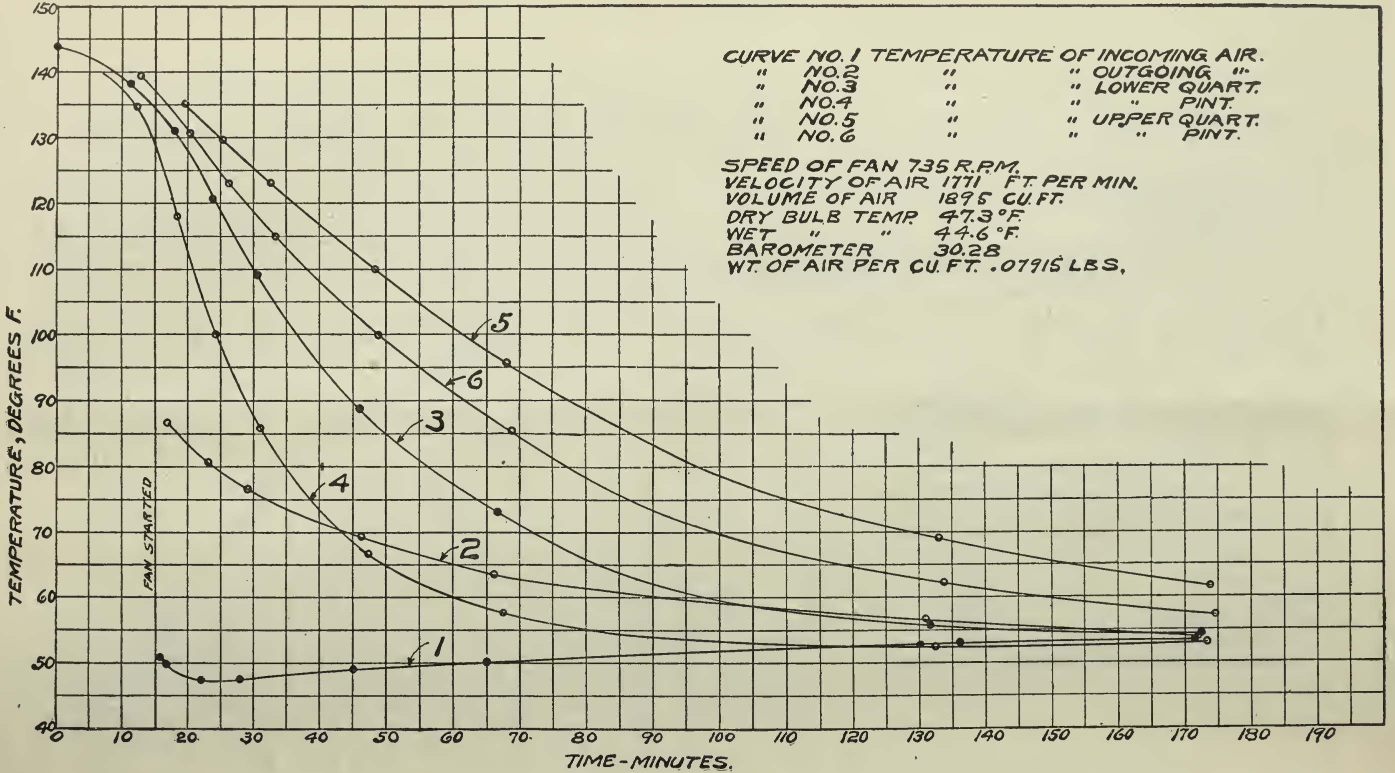

FIG. 7.—Cooling by forced air from bottom upward.—Difference in temperature between top and bottom bottles and incoming and outgoing air. Air in at bottom and out at top.

only about 5° F. (2.8° C.). Therefore, if the crates containing pint bottles were stacked on top of those containing the quarts, the temperature throughout the stack could be equalized to a certain extent. This would require, however, extra care and trouble in stacking.

The curves in figure 8 are plotted from temperatures taken in quart bottles in the first, third, fourth, and fifth tiers of crates, the bottles selected having been immediately above one another and in line. On account of not having a thermocouple available, the temperature in the second tier was not taken. Curves 3, 4, 5, and 6 show the difference in temperature of bottles in respect to one another when placed one above the other. It will be noted that the difference in temperature of adjacent bottles decreases rapidly as the distance from the bottom increases and also that there is a wide difference in the temperature of the top and bottom quarts.

The curves 3, 4, 5, and 6, in figure 9, showing the drop in temperature of pints and quarts, are nearer one another than those in figures 6, 7, and 8. This is owing to the initial temperature of the pint bottles being about 13° F. (7.2° C.) lower than that of the quarts. It is of course impracticable to adjust the initial temperatures of different-sized bottles so that the cooling will be more nearly uniform throughout the stack, and these curves are simply included as a matter of general information.

When the cold air is forced in at the bottom of the stack and up through the crates, the variation in temperature in different-sized bottles and the same-sized bottles at different positions in the stack is too great for satisfactory operation, and we do not believe this method would be commercially practicable. Consequently in our next experiments the direction of the air through the stack was reversed periodically, the cold air being blown through from the bottom for 15 minutes and then through from the top for the same period.

BY FORCING THE AIR ALTERNATELY FROM BOTTOM AND TOP.

The series of curves shown in figure 10 shows the effect of reversing the direction of air through the stacks. The air was forced through the stack from the bottom for 15 minutes, then reversed and forced through from the top for the same length of time. This arrangement was tried with the view of bringing the temperature of the top and bottom bottles nearer together. It may be noticed that the numbers on the curves in figure 10 do not correspond to those in the previous figures. As before stated, these numbers refer to the thermometers used in the work, and in the present case thermometers 1 and 2 recorded the temperature of the incoming air—one for the upward flow, the other for the downward flow. Nos. 8 and 9 recorded the outgoing air in a similar way.

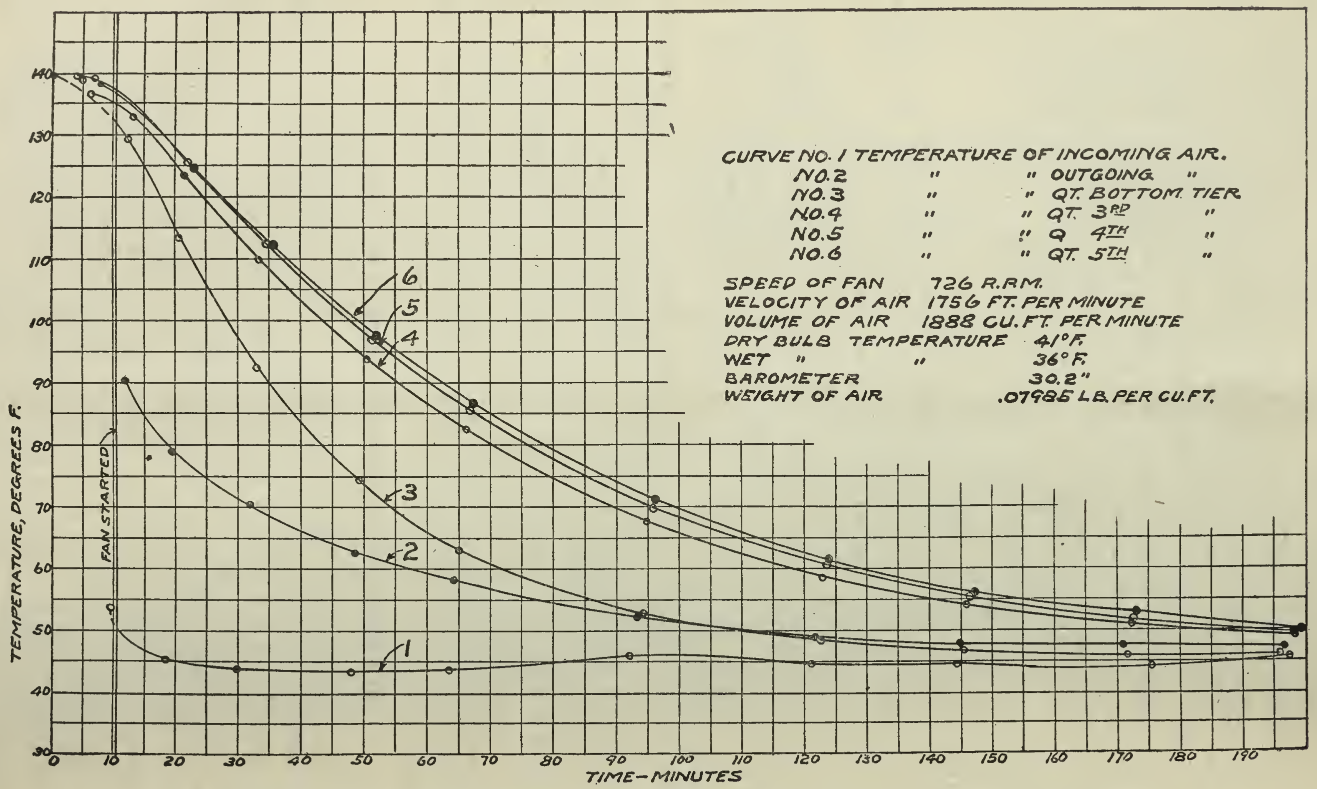

FIG. 8.—Cooling by forcing air from bottom upward.—Relative drop in temperature in bottles at different positions in stack.

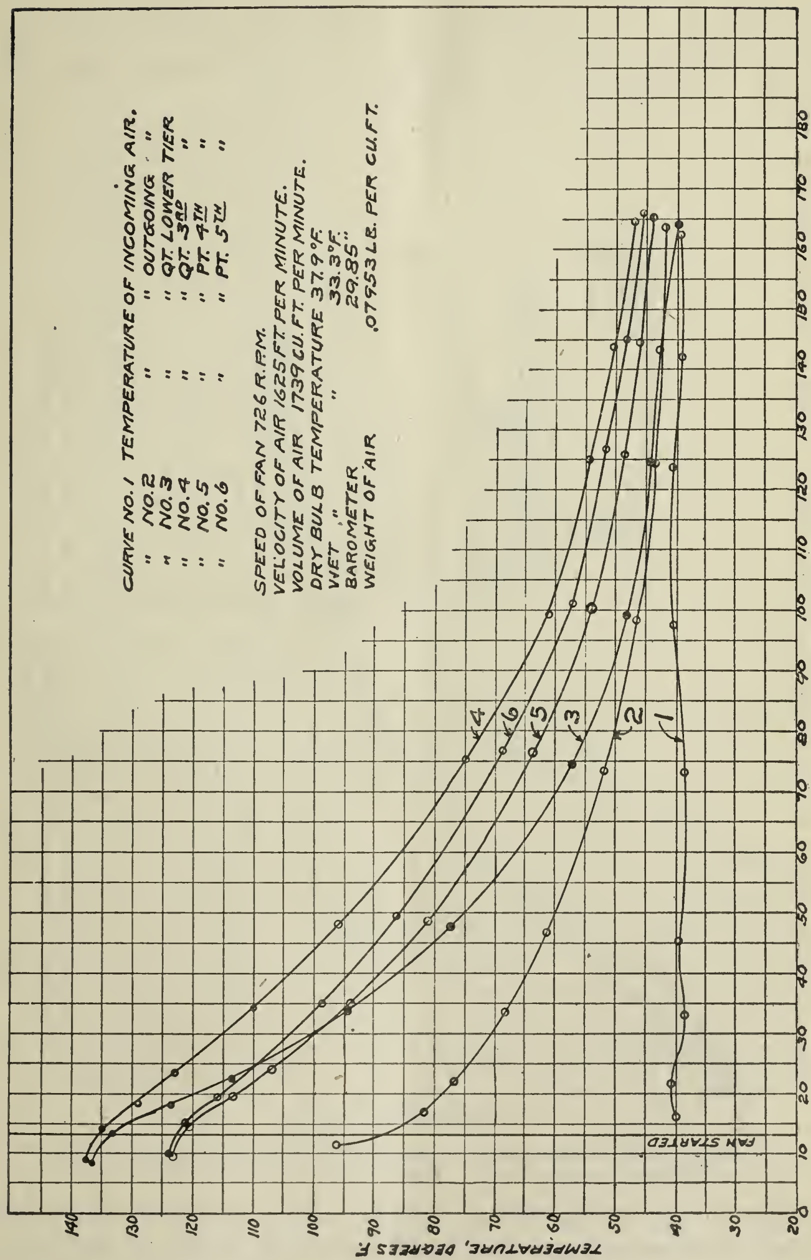

FIG. 9.—Cooling by forcing air from bottom upward.—Relative drop in temperature in bottles at different positions in stack.

While the difference in temperature between the top and bottom bottles was decreased to a certain extent by reversing the air, still there was too great a difference for satisfactory operation commercially, as there is a possibility that some of the bottles are not properly cooled. Furthermore, the arrangement of piping, in order to provide for the reversal of the direction of the air through the crates, was more or less complicated and would involve an increased cost in the installation of the dampers so as to change the direction of the air for cooling on a commercial scale.

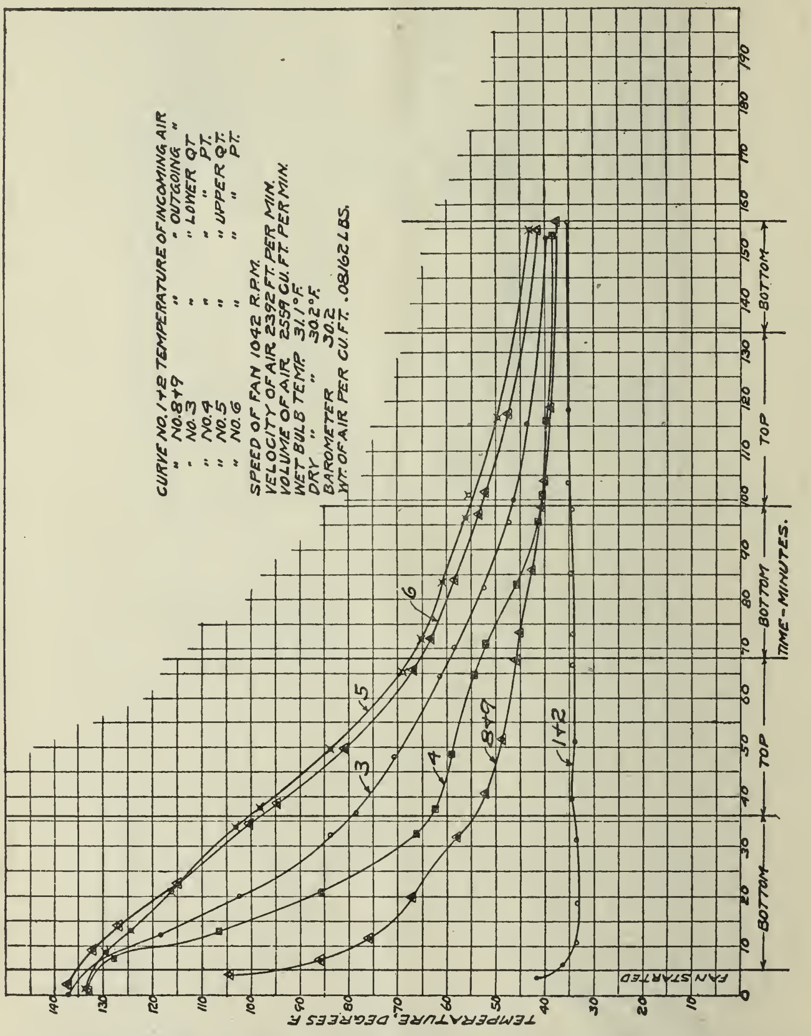

FIG. 10.—Cooling by forcing air alternately from bottom and top.—Difference in temperature of bottles at different positions in stack. Air reversed in direction every 15 minutes.

BY FORCING THE AIR FROM THE TOP DOWNWARD.

As it is natural to expect, the results obtained by admitting the air at the top of the box, forcing it downward through the stacks of crates, and out near the bottom of the box, show that it is by far the best method. With this arrangement the liquid in the upper part of the bottles is cooled first, and of course, owing to its greater density, settles to the bottom of the bottles, allowing the warmer and therefore lighter liquid to rise to the top and take its place. The convection currents are thus taken advantage of, with the result that the extreme difference in temperature between the lower quarts and the upper pints is only a few degrees. In view of this fact the possibility of some of the bottles being insufficiently cooled, while others in extreme cases may be frozen, is remote when this arrangement is used. Furthermore, the rate of cooling was found to be considerably increased by this method as compared with the other two methods. In addition to giving a more nearly uniform temperature throughout the stack, the variation in the temperature of different parts of the same bottle was more nearly the same when the air was forced downward than when blown upward.

From the temperature curves in figure 11 it will be noted that the incoming air is at an average temperature of 40° F. (4.4° C.), and that with an air velocity of 2,512 feet a minute the time required to reduce the temperature of the lower quart to 50° F. (10° C.) was 2 hours and 10 minutes. The average difference in temperature between the lower quart and the upper pint was only 8.9° F. (4.9° C.). In this experiment, as in others, there was some variation in the initial temperature of the liquid before cooling was commenced. In this case the variation amounted to 8° to 10° F. (4.4° to 5.6° C.).

The curves in figure 12 show more plainly the results of cooling by blowing air downward through the stack than those in figure 11, for in the former case the initial temperature of all bottles is practically the same. The average difference in temperature between the lower quart and upper pint (curves 3 and 4, respectively, figure 12), representing extreme conditions both as to size and location of bottles, was only 2.49° F. (1.4° C.), while the maximum difference in temperature between these bottles was only 4.5° F. (2.5° C.). There was a difference of only 2° F. (1.1° C.) between the average and the maximum, showing that the cooling throughout the stack was practically uniform and that with this method all danger that some of the bottles are not thoroughly cooled is eliminated. If the temperature is taken in any one bottle it is safe to assume that the temperatures of the others are within a few degrees of the one taken when the crates are arranged as in the experiment. The average temperature of the incoming air was about 30° F. (−1.1° C.), and the contents of the bottles were cooled to about 50° F. (10° C.) in from 1 hour and 25 minutes to 1 hour and 35 minutes.

The results obtained with inlet air at approximately 20° F. (–6.7° C.) are shown by the curves in figure 13. In this experiment the bottles were cooled to 50° F. (10° C.) in approximately 1 hour and 20 minutes. Generally speaking, with lower temperatures of the inlet air the rate of cooling increases rapidly.

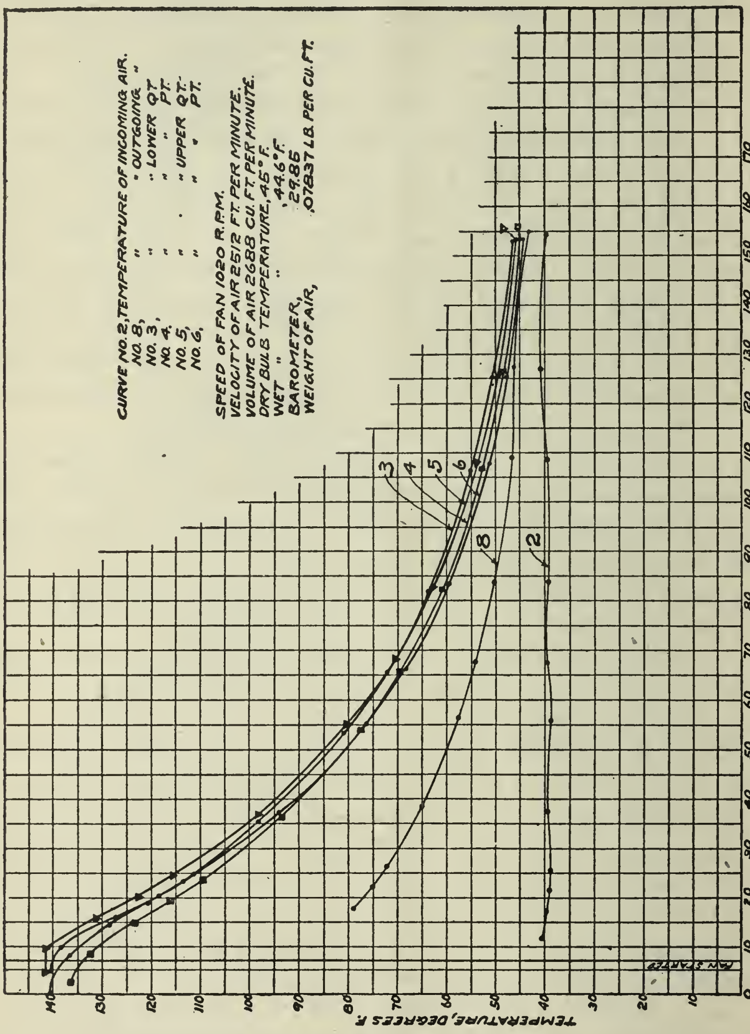

FIG. 11.—Cooling by forcing air from top downward.—Difference in temperature of bottles at different positions in stack.

A study of the curves which indicate the relative drop in temperature of bottles under different conditions and locations when air is blown through the stack from the bottom and from the top will show the advantages of the latter over the former.

TEMPERATURE VARIATIONS IN QUART BOTTLES OF MILK AND WATER UNDER VARYING CONDITIONS.

A differential thermocouple was placed in a quart bottle of milk, another in one of water, and the difference in temperature at the top and bottom of the bottles noted under varying air conditions and directions of flow. One of the junctions of the differential couple was placed about one-half inch above the bottom while the other was placed in the top just beneath the surface of the liquid when the latter was cooled, both being in the center line of the bottle.

The curve in figure 14 shows graphically the difference in temperature between the top and bottom of a quart bottle of milk when cooled by an air blast from the bottom of the stack. The average temperature of the cold-air supply was 39.4° F. (4.1° C.), and the velocity at which the air was blown up through the stack was 1,625 feet a minute. When the fan was started there was a difference of about 8° F. (4.4° C.) in temperature between the top and bottom of the bottle; 22 minutes later the difference had increased to about 23° F. (12.8° C.). Upon standing for a few minutes the bottom layers of milk will naturally be the colder, and with the same source of cold applied to the bottom of the bottle the difference in temperature will of course be increased, owing to the absence of convection currents in the milk itself. The rapidity with which the cooling goes on tends

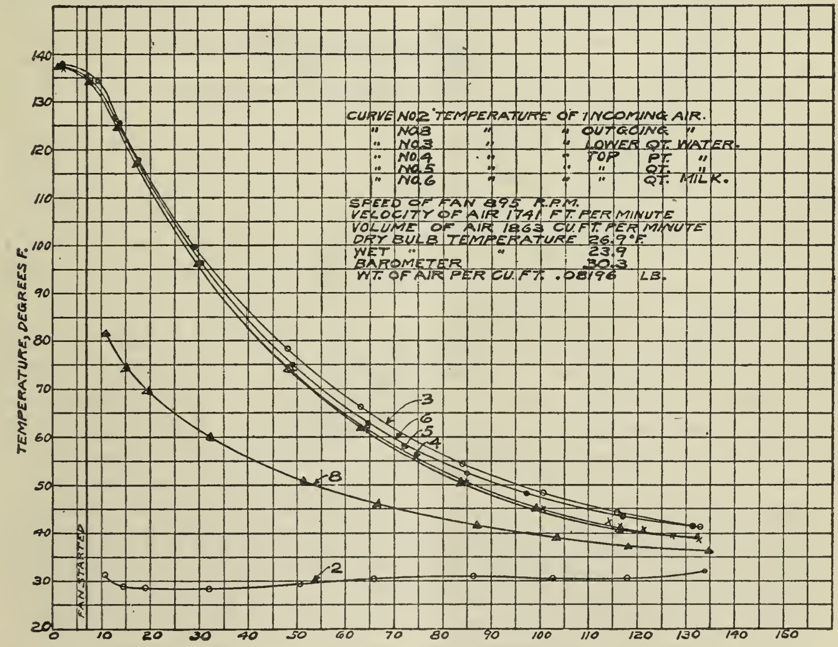

FIG. 12.—Cooling by forcing air from top downward.—Difference in temperature of bottles at different positions in stack.

to vary the difference in temperature between the top and bottom layers; the faster the cooling the greater the difference, and vice versa.

In addition to the wide variation in temperature between the top and bottom layers of milk when cooled by cold-air blast from the bottom of the stack, the whole time required to cool a given quantity is greater than if cooled by admitting the cold air at the top. This point is more fully discussed elsewhere, the principal cause being that when a liquid is cooled in volume the cooling is carried on principally by the convection current set up in the liquid itself and to a lesser extent by conduction.

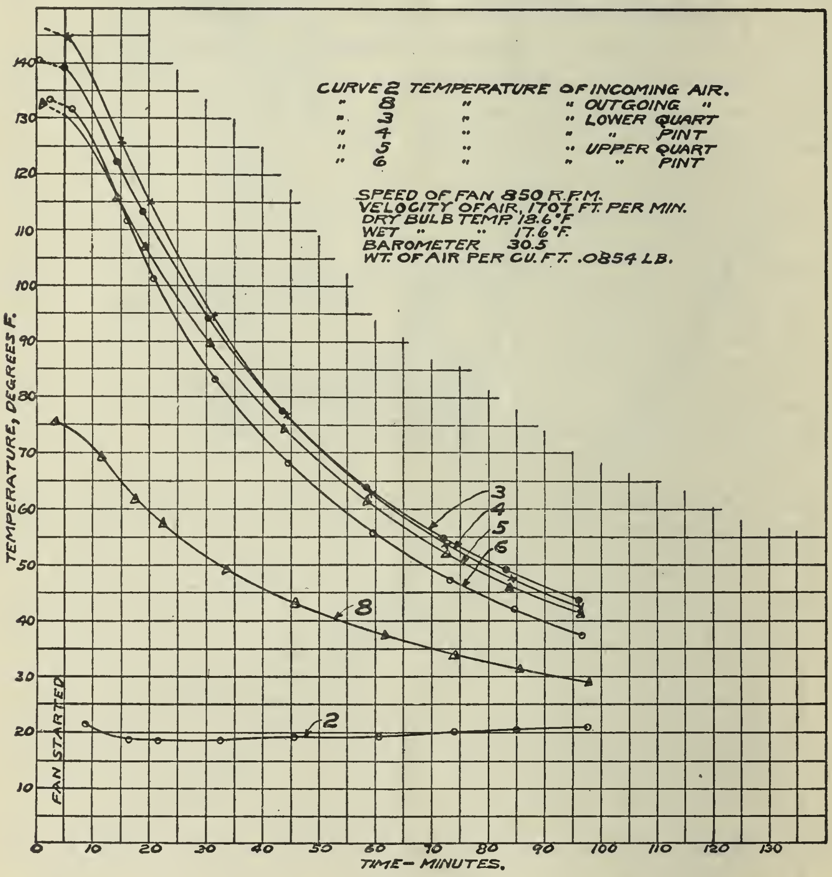

FIG. 13.—Cooling by forcing air from top downward.—Relative drop in temperature of bottles of milk at different positions in stack.

The results obtained by reversing the direction of the air through the stack are now given. The curve in figure 15 shows the results obtained by blowing cold air downward through the stack of crates. The supply of cold air was at an average initial temperature of 39.6° F. (4.2° C.), and the air velocity was 2,512 feet a minute. The air conditions in the two experiments were practically the same, except that the velocity of air in the latter case was considerably greater than in the former.

This experiment was repeated several times under different conditions, but the same general form of curve was obtained each time. Just after the fan supplying the cold air was started the difference in temperature between the top and bottom layers of milk was increased by a degree or two, after which it gradually fell. This slight increase just after starting was probably caused by a quick cooling of the bottom layer which remained at the bottom on account of its greater density, while the top layer gradually fell, its place being taken by a warm layer. These results show the advantage of cooling by blowing air downward through the crates.

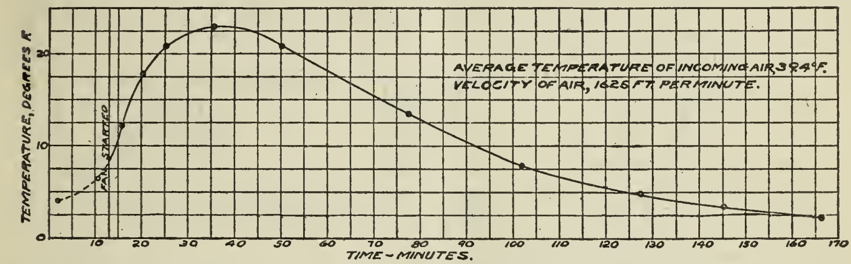

FIG. 14.—Variation in top and bottom of same bottle.—Difference in temperature between top and bottom of quart bottle of milk when cooled by air blown upward through stack.

The curves in figure 16 show the results obtained when either milk or water was cooled by cold air blown downward through the stack, the average temperature of the incoming air being 19.8° F. (– 7.7° C.) and the velocity of air 1,707 feet a minute. It will be seen in the figure that curves 2 and 8 show the variation in temperature of the incoming and outgoing air, while curves 5 and 6 show the drop in temperature of a quart bottle of milk and one of water, respectively. Curve 7 shows the difference in temperature between the top and bottom layers of milk, and curve 10 shows similar temperature differences taken in a quart of water. The solid line marked "0" is intended to represent the point where there is no difference in temperature between the top and bottom layers and is drawn on the temperature scale at 39.1° F. (3.9° C.), representing the maximum density of water. Readings below the zero line as a matter of convenience are considered as minus, and those above as plus. Curve 10, representing the action of water, is not so difficult of interpretation, but on the

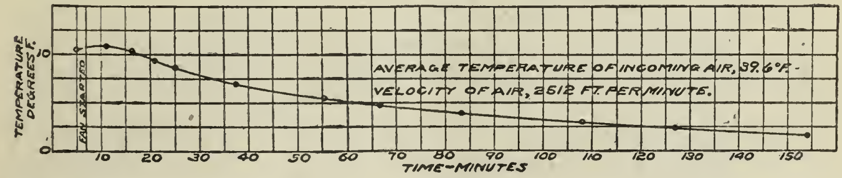

FIG. 15.—Variation in top and bottom of same bottle.—Difference in temperature between top and bottom of quart bottle of milk when cooled by air blown downward through stack.

other hand the action of the milk as represented by curve 7 is very difficult, owing to complications produced by the physical properties of milk under changing temperature conditions.

In curve 10 it will be noted that there was an increase in the difference in temperature between the top and bottom layers of the water just after the fan was started. This may be explained by the fact that there was an air space between the top of the liquid and the paper-cap covering which acted as a heat insulator, protecting the top layer of the water from the direct effect of the cold air, while the bottom layer, which was in direct contact with the bottom of the bottle, was chilled quickly, increasing the difference in the temperature between the top and bottom layers. The upper terminal of the differential couple was placed in the center of the neck of the bottle; hence with the air space in the bottle neck the top layer of the water was cooled to a great extent by conduction from the sides. There

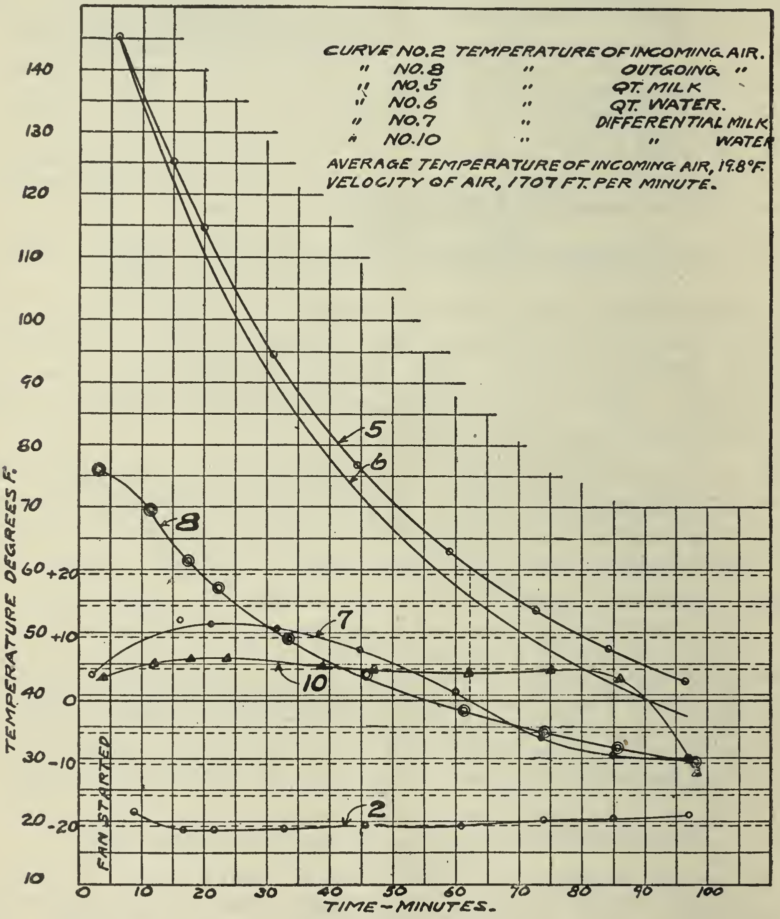

FIG. 16.—Relative drop in temperature of quart bottles of milk and water and incoming and outgoing air; also difference in temperature between top and bottom of quarts of milk and water. Air blown downward through stack.

was but little difference between the top and bottom layers of water until the temperature dropped to near the point of maximum density of water. At 39.1° F. (3.9° C.) there was no difference between the bottom and top layers of water; below this temperature the bottom became the warmer, and the convection currents in the liquid were reversed.

The same general action took place in the quart bottle of milk; the readings, however, were reversed at 60° F. (15.6° C.), as indicated by the vertical dotted line from the point where curve 7 crosses the line of maximum density of water to the intersection of curve 5. Before this point was reached the top layers of milk were the hotter; afterwards the bottom ones showed the higher temperature. The maximum density of milk occurs just above the freezing point, which is about 31° F. (−0.6° C.); hence it might be expected that the top would remain the warmer above that temperature and that there would be no reversal in the readings of the thermocouples. This was not the case, however, in these experiments. There are several factors which may have influenced and probably did affect the cooling, among them being:

1. The placing of the upper couple above the cream line.
2. The rising of the cream to the top of the bottle.
3. Variation in the specific heat at different temperatures.
4. Increase in viscosity with decrease in temperature.
5. Increase in cohesion with lowering temperature.
6. The rapidity at which cooling took place.
7. Convection currents in milk only and not in the cream.
8. Separation of the constituents in the milk.
9. Relative areas of parts of bottle exposed to the cold air.
10. Relative positions of couples from top and bottom of bottles.

COST OF COOLING BY MEANS OF COLD OUTSIDE AIR.

To determine the cost of cooling by using cold outside air, the readings which appear below are given. These data were obtained from an experiment in which air at about 40° F. (4.4° C.) was blown down through the crates of bottles. The temperature curves are shown in figure 12.

Dry-bulb temperature	45° F. (7.2° C.).
Wet-bulb temperature	44.6° F. (6.99° C.).
Difference	.4° F. (0.23° C.).
Barometer	29.85.
Weight of air per cubic foot	0.07837 pound.
Velocity head	0.40 of an inch of water.
Average temperature of outgoing air	58.1° F. (14.5° C.).
Average temperature of incoming air	39.6° F. (4.2° C.).
Cross-sectional area of pipe	1.07 square feet.
Average speed of fan	1,020 R. P. M.
Average volts	98.
Average ampere	20.
Total time of operation	148.5 minutes.

The velocity of air calculated from the Pitot-tube readings is $997\sqrt{\frac{.4}{.07837}}=2,253$ feet a minute, and the volume of air discharged each minute is $2,253\times1.07=2,410$ cubic feet. The readings, however, were taken in the discharge pipe after the air had been heated by passing over the hot bottles; hence the volume of cold air supplied should be corrected in the ratio of the absolute temperatures of the air at the inlet and outlet of the box, or $\frac{2,410\times499}{517}=2,326$ cubic feet of cold air supplied each minute.

The time of operating was 148.5 minutes to cool to approximately 45° F. Therefore the total amount of air supplied for cooling was $148.5\times2,326=345,411$ cubic feet at an average temperature of 39.6° F. (4.2° C.), or a total weight of $345,411\times0.07838=27,069$ pounds.

The heat required to raise the temperature of this amount of air and perform the work of expanding the air, which was furnished by the liquid, bottles, and crates inside the box, is $27,069\times0.169(58.1-39.6+\frac{1}{778}\times18(357,785-345,411)=84,919$ B. T. U. In other words, 34,919 B. T. U. is the amount of heat absorbed from the materials inside the box, and it is obvious that the heat given up by these materials should theoretically equal or balance the amount absorbed by the air.

Following are data and calculations of the amount of heat given up by the liquid, glassware, and crates:

Weight of water used in experiments	677 pounds.
Initial temperature of water	137.4° F. (58.55° C.).
Final temperature of water	45.7° F. (7.61° C.).
Difference	91.7 F. (50.94° C.).
Weight of glass	572 pounds.
Initial temperature of glass	137.4° F. (58.55° C.).
Final temperature of glass	45.7° F. (7.61° C.).
Difference	91.7° F. (50.94° C.).
Weight of wood in crates	189 pounds.
Initial temperature of wood	79.0° F. (26.11° C.).
Final temperature of wood	43.3° F. (6.28° C.).
Difference	35.7° F. (19.83° C.).
Weight of iron in crates	198 pounds.
Initial temperature of iron	79.0° F. (26.11° C.).
Final temperature of iron	43.3° F. (6.28° C.).
Difference	35.7° F. (19.83° C.).
Average temperature of air in room	70.0° F. (21.1° C.).
Average temperature of outgoing air	58.0° F. (14.4° C.).
B. T. U.[1] extracted from water, 677 (137.4−45.7)	=62,080
B. T. U. extracted from glass, 572×0.1877 (137.4−45.7)	= 9,848

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[1] Fahrenheit degrees were used in the calculations; hence results are in B. T. U.

B. T. U. extracted from wood, $198\times0.5\ (79.0-43.3)$	= 2,534
B. T. U. extracted from iron, $198\times0.113\ (79.0-43.3)$	= 799
	75,261
B. T. U. through walls of box, $\frac{296\times4(70-58)2.47}{24}$	= −1,462
	73,799

The foregoing figures indicate that 12 per cent more heat was taken out than the material gave up, which, of course, is impossible; hence it is believed that the Pitot-tube readings were wrong, as the weight and temperature of the material were carefully determined and are believed to be correct. On the other hand, if the anemometer readings of air velocities are taken and calculations made with them as a basis, the two sets of calculations balance within 2 per cent. In other words, 98 per cent of the heat given up in cooling the liquid, glassware, and crates is accounted for in the heat balance, showing that all our observations were practically correct. With this, then, as a basis, the total amount of refrigeration performed was $\frac{73,799}{288,000}=$ 0.26 ton, or at the rate of 0.106 ton an hour. The horsepower input to the motor $=\frac{98\times20}{746}=2.6$. The efficiency of the motor, however, was not determined, but in view of the fact that it was designed for a voltage of 120 and was operated at a voltage of only 98, its efficiency was necessarily low. Under the operating conditions, and assuming a cost of 6 cents a kilowatt hour for electric energy, the cost of power per ton of refrigeration was $1.11. When the air supply is colder, the time required to cool the milk is, of course, shorter; hence the cost of power is decreased. The over-all efficiency of a direct-connected blower set of this size and type when operated under normal service conditions should be about 40 per cent, but under our conditions it was only about 22 per cent; hence the cost of power for cooling in these experiments is considerably greater than it should be in a commercial plant. If the over-all efficiency of the blower set is assumed to be 40 per cent, then the total cost of electric energy, under the conditions mentioned above, and at a cost of 6 cents a kilowatt hour, would be only about 66 cents a ton of refrigeration.

As the blower set used in these experiments was operated very inefficiently, the cost of cooling is not typical of this method. The figures obtained do serve, however, to show that the cost of cooling by means of circulating cold outside air is very small. Of course, this can not be done throughout the year, but in a great many localities cooling may be accomplished by circulating cold outside air through the refrigerating rooms during several months of the year. In summer the air would have to be cooled artificially. This, however, is being done in a large number of milk plants which cool the air in a separate coil room and circulate it through the milk-storage room for the purpose of holding a low temperature in the room, the milk being cooled by running over some form of cooler before it is bottled and placed in the room.

It seems probable, from our results on a small experimental scale, that with outside air at a temperature of 40° F. (4.4° C.) or below, the process of cooling hot bottled milk can be successfully accomplished by forced circulation. No artificial refrigeration of the air is then necessary.

EFFECT OF SLOW COOLING ON THE BACTERIAL FLORA OF MILK AFTER PASTEURIZATION.

It is believed that any system of pasteurization in which the milk is not cooled immediately after heating will be looked upon with suspicion and will excite comment. It has always been supposed that immediate cooling was an indispensable part of the process of pasteurization (1) because sudden changes in temperature were believed to have a destructive effect on the bacterial cells and (2) because it has been supposed that bacteria left after pasteurization would immediately begin to grow unless the milk were cooled at once. It has been shown by Ayers and Johnson [1] that sudden cooling plays no part in the destruction of bacteria. One question, therefore, remains to be answered: How quickly must pasteurized milk be cooled in order to check bacterial growth?

From former studies of pasteurization it seemed apparent that the bacteria which survived heating were somewhat weakened or, at least, did not begin to grow, as might be expected. These observations naturally gave rise to the idea that pasteurized milk might be cooled directly in bottles by a forced-air circulation, provided the cooling period did not extend over more than a few hours.

In order to obtain data on this question 10 experiments were made, in which milk was first pasteurized and bottled hot in steamed bottles. In each experiment one of two bottles was then cooled to 45° F. (7.2° C.) within half an hour in ice water and held at that temperature in a refrigerator for 17½ hours, the other bottle being cooled slowly at room temperature for 4 hours and placed in a refrigerator at 45° F. (7.2° C.) for 14 hours. At the end of that time each bottle of milk was 18 hours old; one had been cooled slowly and had been at 45° F. (7.2° C.) for probably a very short time, because, although it had been in the refrigerator for 14 hours, the milk was warm when placed there and cooling in still air is a slow process. Both bottles after the 18-hour cooling period were allowed to stand for 6 hours at temperatures of from 75° to 85° F. (23.9° to 29.4° C.). The bacterial results are seen in Table I.

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[1] Ayers, S. Henry, and Johnson, W. T., jr. A study of the bacteria which survive pasteurization. Bul. 161, Bureau of Animal Industry. 1913.

Table I.—*Bacterial growth in milk during a quick and slow cooling to 45° F., followed by holding for 6 hours at warm temperatures (bacteria in 1 c. c.).*

	Sample No.									
	1	2	3	4	5	6	7	8	9	10
Raw milk	95,000	176,000	176,000	97,500	97,500	......	450,000	......	985,000	38,000
Milk cooled quickly:										
Directly after pasteurization	600	1,870	1,570	5,900	5,900	22,900	890	4,800	8,300	5,500
After 18 hours held at 45° F.	1,000	[1] 2,050	[1] 2,370	......	......	16,600	1,700	2,500	8,900	5,200
Sample then placed for 6 hours at 86° F.	......	5,750	8,400	6,600	5,900	......	......	......	[2] 9,600	[2] 5,200
Milk cooled slowly:										
Directly after pasteurization	860	1,320	1,220	5,900	5,900	21,800	890	5,400	7,500	6,500
Cooled slowly at room temperature for 4 hours and placed for 14 hours in refrigerator at 45° F.	500	1,180	5,520	......	......	12,300	2,200	715	9,800	5,200
Then placed for 6 hours at 86° F.	......	5,800	6,100	3,700	3,700	......	......	......	[2] 8,900	[2] 5,300

[1] Held at 45° F. for 21 hours, in place of 18 hours.

[2] Held at 75° F., instead of 86° F.

As may be seen in Table I, bacterial counts were made on each bottle of raw milk directly after pasteurization, at the end of the 18-hour cooling period, and again after the milk had been at room temperature for six hours. The results obtained showed that there was no more increase in the pasteurized milk cooled slowly than in similar milk cooled within half an hour and held at low temperatures for 18 hours. Neither was there any difference in the bacterial numbers, even after milk cooled by both processes had been removed, after 18 hours' cooling, and allowed to stand for 6 hours.

The various counts from the 10 samples are averaged in Table II, in order to show more plainly the effect of the two systems of cooling on the bacterial numbers in milk.

Table II.—*Summary of results from Table I.*

Milk and stage of cooling process.	Average bacteria per c.c.
Cooled quickly:	
Directly after pasteurization	5,823
After 18 hours in refrigerator	5,040
Taken from refrigerator and held 6 hours at temperatures from 75° to 86° F	6,908
Cooled slowly:	
Directly after pasteurization	5,729
Cooled slowly at room temperature for 4 hours and held in refrigerator for 14 hours at 45° F.	4,678
Taken from refrigerator and held for 6 hours at temperatures from 75° to 86° F.	5,583
Raw milk	264,375

It will be seen in this table that the average bacterial counts of milk cooled slowly, made at different times, are even lower than those of milk cooled quickly. While this difference is possibly an experimental error, it is evident that bacterial growth in the pasteurized milk was not increased by the slow-cooling process.

We do not wish to convey the idea that pasteurized milk need not be cooled at all. The cooling of any milk is absolutely essential in order to restrain bacterial growth, and we wish to emphasize the fact that the process of cooling pasteurized milk slowly does not eliminate the cooling process, but simply makes use of a slower cooling process than is in use at present.

In order to show, respectively, the effect of cooling quickly, cooling slowly, and not cooling to low temperatures at all, three experiments were made. Milk was pasteurized in bulk, and three steamed and hot quart bottles were filled with hot milk. One bottle was cooled in ice water in half an hour to 50° F. (10° C.) and refrigerated at 45° F. (7.2° C.). Another bottle was cooled in a blast of air at room temperature for half hour, during which time the temperature dropped from 145° F. (62.8° C.) to about 100° F. (37.8° C.). The milk was then allowed to stand at a temperature of from 100° to 80° F. (37.8° to 26.7° C.) for five hours, after which it was placed in a refrigerator at 45° F. (7.2° C.), where it cooled slowly in still air. The other bottle was cooled for half an hour in an air blast at room temperature and allowed to remain at a temperature of about 75° F. (23.9° C.) throughout the experiment. The results of these experiments, in which bacterial counts were made at different stages of the cooling process, are given in Table III.

TABLE III.—*Effect of different methods of cooling on the bacterial content of pasteurized milk (bacteria in 1 c. c. of milk.)*

	Sample No.		
	1	2	3
Raw milk	9,050,000	....	11,900,000
Cooled quickly:			
Directly after pasteurization	6,450	2,110	8,500
Held at 45° F. for 22 hours	5,050	1,720	28,400
Held at 75° F. for 6 hours	4,800	2,340	76,500
Held at 75° F. for 24 hours	1,370,000	885,000	....
Cooled slowly:			
Directly after pasteurization	7,150	2,580	11,900
Held at 80° to 100° F. for 5 hours	6,100	1,600	29,000
Held at 45° F. for 17 hours	6,200	2,400	192,000
Held at 75° F. for 6 hours	9,600	2,740	348,000
Held at 75° F. for 24 hours	2,760,000	850,000	....
Allowed to cool naturally in air 75° F.:			
Directly after pasteurization	4,950	2,180	8,500
Held at 75° F. for 5 hours	6,850	2,890	25,000
Held at 75° F. for 22 hours	700,000	2,420,000	83,400,000
Held at 75° F. for 28 hours	2,750,000	13,400,000	269,000,000
Held at 75° F. for total of 66 hours	460,800,000	....	....

A study of the table shows that there was no increased bacterial growth in experiments 1 and 2 caused by holding the pasteurized milk for five hours after bottling hot, even though the temperature during that period ranged from 100° to 80° F. (37.8° to 26.7° C.), which is the most favorable temperature for bacterial development. In experiment 3 there was an increased growth compared with that in the milk cooled quickly. It must be remembered that these experiments represent extreme conditions in slow cooling, but the fact is apparent that the cooling process should not extend over five hours. The effect of not cooling milk to low temperatures is plainly shown in the table by a comparison of the bacterial counts with those of milk cooled both quickly and slowly.

The results which have been thus far presented on the bacteriological effect of slow cooling were obtained from observations of bottles held under extreme laboratory conditions. We realize that laboratory experiments do not always apply to commercial conditions, so the results shown in Table IV were determined from experiments conducted on a 30-crate basis. Two quart bottles of milk were examined in each experiment. The crates were stacked five high, and one bottle was placed in the lower crate and the other in the upper one. The cooling was conducted in the usual way, 30 crates being stacked in the cooling box, as has been described. This table shows the bacterial content of the raw milk, the bacterial content of the hot pasteurized milk bottle immediately after pasteurization for 30 minutes at 145° F. (62.8° C.), and also the bacterial content after the bottles had been cooled by forced-air draft.

TABLE IV.—*Effect of slow cooling on bacterial content of pasteurized milk (milk cooled on a small commercial scale).*

Experiment No.	Bottle No.	Bacteria per cubic centimeter.			Length of cooling period.
		Raw milk.	After pasteurization for 30 minutes at 145° F.	After cooling by forced-air circulation.	
					Minutes.[1]
1	1	490,000	5,400	3,850	155
	2		7,100	2,850	
2	1	128,000	5,000	3,900	150
	2		4,400	4,400	
3	1	12,800,000	155,000	18,900	148
	2		156,000	13,900	
4	1	140,800,000	525,000	32,000	127
	2		555,000	50,500	
5	1	7,400,000	132,000	95,500	93
	2		161,000	78,500	

[1] Milk cooled to about 75° F.; in all the other experiments the milk was cooled to below 50° F.

In experiment 1 the milk was cooled during a period of 155 minutes to about 75° F. (23.9° C.) only, as the outside air was warm, but as will be seen from the results the bacterial count was even lower after cooling than before. In the other four experiments the milk was cooled to below 50° F. (10° C.), and the length of the cooling period varied from 93 to 150 minutes. It is interesting to note that when the bacterial count in the raw milk was high, there was a marked reduction in the number of bacteria during the process of cooling by forced-air circulation. When the bacterial content of the raw milk was low, the reduction caused by slow cooling was not so marked, although the bacterial count was usually less.

From the foregoing experiments, conducted on a laboratory and also on a small commercial scale, it seems evident that there is no bacterial increase in pasteurized milk which is cooled slowly; on the contrary, there is often a decrease, especially when there are large numbers of bacteria in the milk before pasteurizing.

These results are of particular value, for they indicate that it is possible to cool hot pasteurized milk slowly by means of forced-air circulation. From the results of our experiments we believe this is possible without any bacterial increase in the milk, provided the cooling to 50° F. (10° C.) does not require a longer period than five hours. This period of time should not be exceeded. It should be remembered that even if a period of three hours is required to cool milk from 145° F. (62.8° C.) to 50° F. (10° C.), the temperature is within the growing range of bacteria for only a portion of that period. With the process of cooling by forced-air circulation on a commercial scale milk can be cooled to 50° F. (10° C.) within three hours, which is well within the 5-hour limit, and in order to have a wide margin of safety we recommend that hot-bottled pasteurized milk be cooled within three hours after it is bottled.

We wish to emphasize the fact that the bacteriological results which have been discussed apply only to the slow cooling of hot pasteurized milk during the process described in this bulletin. Pasteurized or raw milk must be held, after the cooling process, at low temperatures in order to check bacterial development.

EFFECT OF THE PROCESS ON THE CREAM LINE AND FLAVOR OF MILK.

In the consideration of the process of bottling hot pasteurized milk followed by slow cooling, it is of practical importance to know what effect such a process will have on the cream line and flavor of milk. Several laboratory experiments were first made to determine this matter. Milk was pasteurized, and hot 500 c. c. graduated cylinders were filled with hot milk up to the 500 c. c. mark. Together with the cylinder of hot pasteurized milk one cylinder was filled with raw milk and one with pasteurized milk which had been cooled to 50° F. (10° C.) in 15 seconds by running through a coil immersed in brine. The method of cooling the hot-bottled pasteurized milk was varied considerably, as may be seen in Table V. After holding the milk for 24 hours at 45° F. (7.2° C.) the numbers of cubic centimeters of cream were read off directly from the graduations on the cylinder. This method, of course, gave a very reliable means of determining the effect that heating and cooling had on the cream line; in fact, it was too accurate, since the marked differences in the cream line seen in the cylinders were not apparent in the bottled milk.

TABLE V.—*Laboratory cream-line experiments showing comparison of raw milk and milk pasteurized at 145° F. for 30 minutes followed by various methods of cooling.*

Experiment No.	Milk and process.	Cream in 500 c. c. cylinder after 24 hours' refrigeration at 45° F.
		C. c.
1	Raw	64.5
	Pasteurized:	
	Cooled quickly in 15 seconds to 50° F	64.5
	Cooled slowly in air blast for 45 minutes	65.0
	Held above 105° F. for three hours and cooled in ice water	64.5
2	Raw	65.0
	Pasteurized:	
	Cooled in 15 seconds to 50° F	62.5
	Cooled slowly in air blast for 1½ hours	52.5
	Held above 100° F. for 1½ hours	52.5
3	Raw milk lost	....
	Pasteurized:	
	Cooled in 15 seconds to 50° F	83
	Cooled slowly for 30 minutes in air blast, then cooled quickly in brine	85
	Held above 100° F. for 3 hours, then cooled quickly in brine	90
4	Raw milk lost	....
	Pasteurized:	
	Cooled in 15 seconds to 50° F	75
	Cooled slowly in air blast for 2½ hours, then cooled in ice water	69
	Held above 100° F. for 2½ hours and cooled in ice water	75
5	Raw	80
	Pasteurized:	
	Cooled in 15 seconds to 50° F	68
	Cooled slowly in air blast for 2 hours	55
	After cooling in air blast for 2 hours the milk was cooled quickly in brine to 50° F.	62
	Held above 100° F. for 5 hours	55
	After holding above 100° F. for 5 hours the milk was cooled quickly in brine to 50° F.	62

A study of the results shown in the table above indicates that cream-line formation is a variable factor. Sometimes it was reduced by pasteurization, even when the milk was cooled to low temperatures within 15 seconds, and at other times there was no difference. In some experiments the cream line was slightly less on milk cooled slowly.

These laboratory experiments do not exactly duplicate conditions of air cooling on a commercial scale, for in no case was the hot pasteurized milk cooled to 50° F. (10° C.) within three hours, as it was in our later experiments. Throughout our experiments on a small commercial scale, when the milk was cooled to that temperature within the time named no apparent reduction of the cream layer was observed, and the cream line was always distinct. When milk stood at temperatures above 80° F. (26.7° C.) for several hours without agitation, some of the melted butterfat rose to the top of the bottle and on cooling formed a small lump of butter. This was observed, however, when the cooling process was begun immediately after bottling, even though the cooling was gradual.

As to the effect of the process on the flavor of the milk, it may be said that there was no more noticeable flavor than is the case with milk pasteurized and cooled rapidly, except when the milk was held above 100° F. (37.8° C.) for several hours. This was the case in several of our experiments, and in these a slightly more pronounced cooked taste was noticeable in the milk. In this connection we wish to call attention to the fact that these results hold good only for milk pasteurized at 145° F. (62.8° C.) and are based on results obtained experimentally on a small scale. They can not be applied where higher temperatures might be used, as in such cases it is possible that different results may be obtained.

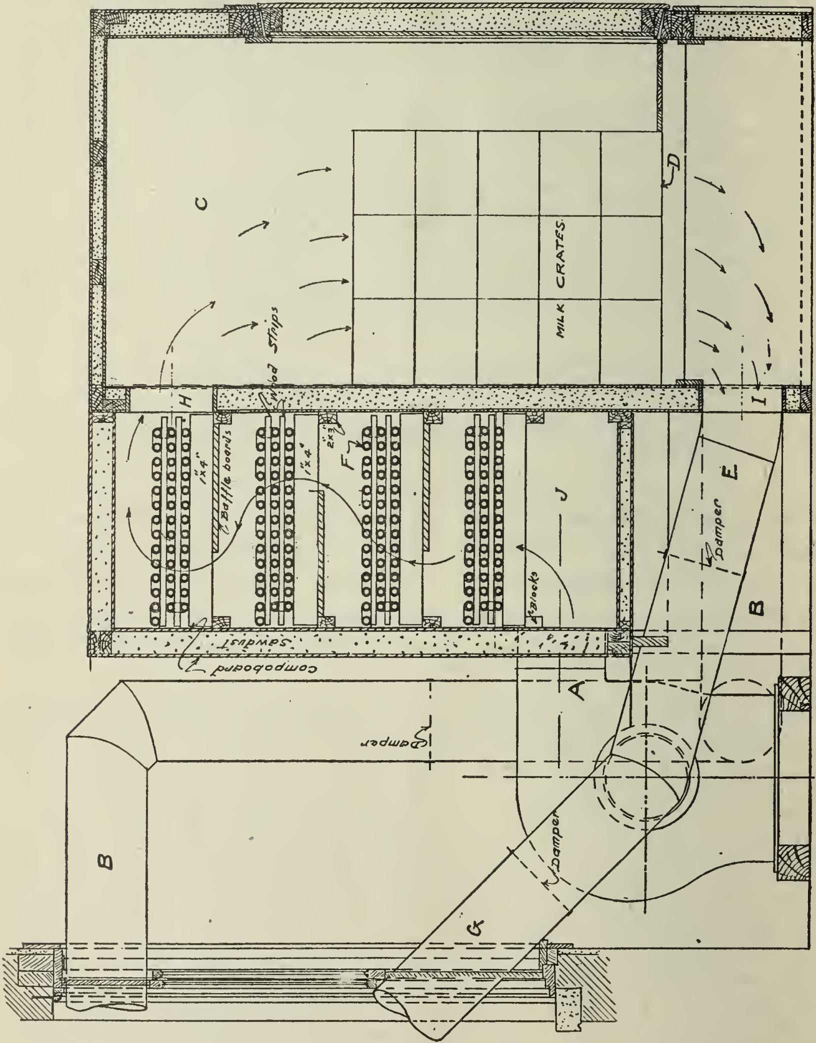

FIG. 17.—General arrangement of heating apparatus.

EXPERIMENTS IN HEATING BOTTLED MILK BY FORCED AIR.

The experimental apparatus used for heating the milk in the bottle by means of circulated hot air is shown in figure 17. It is the same general arrangement that was used for the cooling experiments except the addition of the bunker and heating coils. The crates were stacked in the box as shown, and the air was forced by the fan from the heating-coil bunker into the top of the box, down through the stack of crates, and out at the bottom. The floor of the box was made practically air-tight around the crates, so that the hot air necessarily had to flow through the crates and around the bottles in its passage from the box.

In figure 17 it will be noted that the galvanized piping for air was so arranged that by manipulating dampers a closed hot-air circuit would be maintained for heating, or cold air from the outside could be admitted to the box for the purpose of cooling. By closing the dampers in inlet pipe G and outlet pipe B and opening the damper in pipe E a closed hot-air circuit would be maintained in which the fan A would draw the hot air from the bottom of the box and force it upward around the heating coils and into the top of the box through the opening H, thence downward through the crates.

After heating the liquid to the desired point, the steam supply was cut off, the dampers were reversed, and cold outside air admitted to the box for cooling; that is, the dampers in pipes G and B were opened, and the one in pipe E closed. Then cold air from the outside was drawn in by the fan A, forced up through the heating coils and into the box through the opening H, thence downward through the crates, and outside through the pipe B. The heating coils were so arranged that the number of coils could be varied, thus making it possible to regulate the amount of heat in the box. The steam pressure and the amount of condensed steam from the coils were recorded during the experiments.

RESULTS OF HEATING FROM BOTTOM UPWARD.

Before the equipment was arranged as shown in figure 17, the heating coils were placed in the bottom of the box, under the platform, and the air was forced by the fan around the coils and upward through the stack of crates, leaving the box near the top. After the liquid was heated to the desired point, cold air for cooling was blown downward through the crates. The results obtained under these conditions are shown by the curves in figure 18. It will be seen that there was a wide variation in the temperatures of bottles at different parts of the stack.

After heating there was an average difference of 16° F. (8.9° C.) between the top and bottom quarts of milk, and a maximum difference of about 30° F. (16.7° C.). This variation in temperature is considered too great for satisfactory pasteurization, as certain bottles will be overheated while others will not be heated to the required point; furthermore, there is a variation in temperature of from 10°

to 15° F. (5.6° to 8.3° C.) between the top and bottom portions of milk contained in the same bottle. This is shown graphically in figure 19, the curves in which were plotted from data obtained in the experiment shown in figure 18. The distances of the curves above the zero line are considered as positive, and those below as negative. The points where the curves cross the zero line indicate equal temperatures at top and bottom of the bottle; hence the convective currents cease at these points. Above the zero line the topmost layers were the hottest, and below it the bottom ones were the hottest. It is of course very important that the milk be heated uniformly throughout the stack as well as in individual bottles; therefore it is believed that this method of heating will not give the desired results.

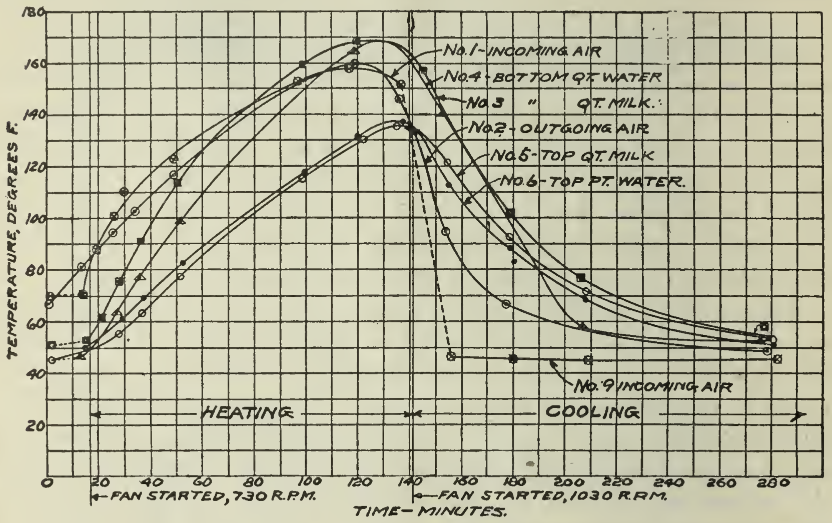

FIG. 18.—Heating and cooling by forced air.—Variation in temperature of bottles at different positions in stack when heating and cooling. Hot air in at bottom when heating and cold air in at top when cooling.

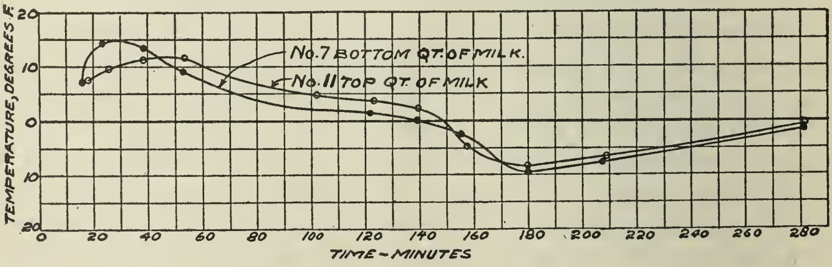

FIG. 19.—Heating by forced air.—Variation in temperature between top and bottom layers of milk in same bottle. Same experiment as in fig. 18.

RESULTS OF HEATING FROM TOP DOWNWARD.

After making several experiments with the heating coils in the bottom of the box, all of which gave unsatisfactory results, the arrangement of apparatus shown in figure 17 was used. With this arrangement the air was blown over steam coils and down through the crates, leaving the box near the bottom. The results are shown by means of curves in figure 20. In this case the crates were stacked five high, the pint bottles in the three lower crates, and the quarts in the two upper ones. By placing the quart bottles on top they came first into contact with the hottest air and naturally would be heated more quickly than the pint bottles at the bottom. There was still a wide difference in temperature, however, between the upper and lower tiers of bottles and also in the temperature of the top and bottom layers in the same bottle, where a maximum temperature difference of 82° F. (45.5° C.) was observed. It was therefore decided that neither of these methods is commercially practicable when the milk is contained in bottles.

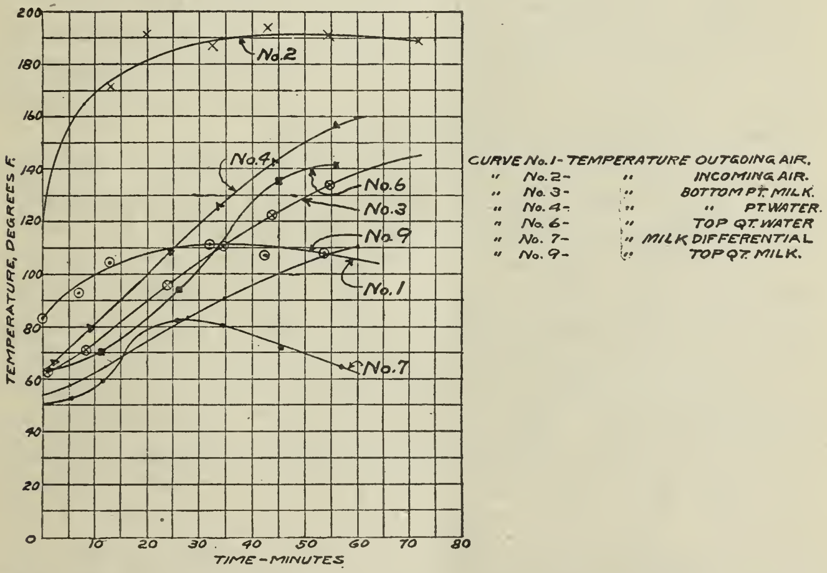

FIG. 20.—Heating by forced air.—Variation in temperature of bottles at different positions in stack. Hot air blown downward through crates.

GENERAL SUMMARY.

1. In these experiments bottles of water generally were used in place of milk, as it was found that there is very little difference in the relative rate of cooling milk and water. When quart bottles of milk and of water were cooled by forced-air circulation from 148° to 45° F. (64.4° to 7.2° C.), the milk cooled more slowly, but the maximum difference was about 2° F. (1.1° C.). On account of this small variation it was considered advisable to use water, as it was more easily obtained and handled. Bottles of milk, however, were distributed throughout the crates for bacteriological studies as well as for temperature readings.

2. A bottle of hot milk will cool about one-third faster in circulated air than in still air at the same temperature. This is also true of hot milk in 10-gallon cans. The time required to cool through a given range, other things being equal, depends upon the size of the containing vessel, and it is believed that in commercial practice quart bottles are about the largest-sized containers which should be used with this method. Cooling by natural circulation is too slow for satisfactory application on a commercial scale.

3. The cooling experiments were operated on a basis of 30 crates, stacked in 6 piles, each 5 crates high. When cold air was forced up through the crates, there was a wide variation in the temperature in the same sized bottles in different positions in the stack, as well as in quart and in pint bottles in the same position. This variation was too great for satisfactory operation on a commercial scale.

4. When the direction of the cooling air was reversed every 15 minutes during the cooling period, first up then down through the crates, the variation in the temperature of the bottles was reduced, but the cooling was not entirely satisfactory.

5. When air was forced down through the stacks of crates the cooling process was much more effective. The maximum difference in temperature in any of the bottles was about 4.5° F. (2.5° C.), and the average difference only approximately 2.5° F. (1.4° C.) when the bottles were all at the same initial temperature at the beginning of the cooling period. There was a difference of only 2° F. (1.1° C.) between the average and the maximum variation in temperature of different bottles, showing that the cooling was practically uniform. With air at 40° F. (4.4° C.) forced down through the crates at the rate of approximately 2,500 feet a minute, the bottles were cooled from about 140° F. (60° C.) to 50° F. (10° C.) in about two hours. With air at 30° F. (–1.1° C.), and at the rate of about 1,700 feet a minute, the bottles were cooled through the same range of temperature in approximately 1 hour and 30 minutes, and when it was at 20° F. (–6.6° C.) and forced down through the crates at the last-mentioned rate, the bottles were cooled from about 140° F. (60° C.) to about 50° F. (10° C.) in about 1 hour and 20 minutes.

6. There was a wide variation in temperature between the top and the bottom of the same bottle during the cooling period when air was forced up through the crates; this variation was practically eliminated when air was forced downward through them.

7. Cost of cooling by forced-air circulation, when the outside air temperature is 40° F. (4.4° C.) or lower, is materially less than that of the usual methods of refrigeration.

8. Bacteriological studies indicate that if milk is cooled from 145° F. (62.8° C.) to 50° F. (10° C.) within five hours after pasteurizing, no more bacterial increase will take place during the slow cooling

than if the milk were cooled immediately to the same temperature. In fact, in our experiments, on a 30-crate basis, there was a marked reduction in the bacterial numbers during the cooling period, especially when the raw milk contained large numbers of bacteria before pasteurization. From our experiments it seems that pasteurized milk can be cooled, on a commercial scale, from 145° F. (62.8° C.) to 50° F. (10° C.) by means of forced-air circulation within three hours; consequently the process can be completed well within the 5-hour limit. In order to have a wide margin of safety and to obtain the best results, we recommend that the cooling process be started immediately after the hot pasteurized milk is bottled and that it be completed within three hours.

The cooling of milk is absolutely essential in order to restrain bacterial growth, and we wish to emphasize the fact that the process of cooling slowly does not eliminate the cooling process, but simply makes use of a slower-cooling process than is in use at the present time.

9. So far as our laboratory experiments on a 30-crate basis indicate, slow cooling of hot-bottled pasteurized milk has no appreciably detrimental effect on the cream line and the flavor of the milk. This is true for periods of cooling of not more than three hours. It is, of course, possible that different results may be obtained on a large commercial scale.

10. On account of the uneven heating of pint and quart bottles in similar positions, and the same-sized bottles in different position in the stacks, attempts to heat milk in bottles by means of forced-air circulation were not successful. It was found impossible to heat the bottles to the pasteurizing temperature of 145° F. (62.8 C.) without overheating some of them.

CONCLUSION.

Our results indicate that it is commercially practicable to cool hot pasteurized milk in containers not larger than quart bottles by forcing cold air downward over them when the air is at a temperature of 40° F. (4.4° C.) or lower.

On account of overheating portions of the milk, the process of pasteurizing milk in bottles by forcing hot air over them seems commercially impracticable.

This bulletin contains experimental data on the method of cooling hot-bottled milk by forced-air circulation which we believe will be of assistance in the practical application of this method of cooling. When the temperature of the outside air is 40° F. (4.4° C.) or lower, it may be used for this purpose, but when it is higher than that it must be cooled by mechanical refrigeration. It is possible to use a combination of outside air and refrigerated air; that is, outside air at a temperature of, say, 60° or even 70° F. (15.5° to 21.1° C.) may be used to cool the milk partly, the remainder of the cooling being done by mechanical refrigeration. It should be noted, however, that in cooling milk on a large scale by this method some unforeseen difficulties may arise which we did not encounter in our experiments.

This process of cooling by forced-air circulation, if commercially practicable, could be applied to advantage for cooling hot-bottled pasteurized milk. Briefly stated, the complete pasteurizing and cooling process could then be as follows:

Milk could be pasteurized by the ordinary holder system at 145° F. for 30 minutes. It could then be bottled hot in special oversized milk bottles of the ordinary type and capped with ordinary sterile caps. Before being filled, the bottles could be steamed for two minutes by running the crates inverted on a conveyer over steam jets; the bottles would then go through the bottling machine in a hot condition and would be practically sterile. The crates of hot-bottled pasteurized milk could then be cooled by stacking in a refrigerator room and blowing cold air through the crates. In the cold season outside air could be used for cooling, and in the warm season refrigerated air could be circulated through the crates.

This process could be modified in two ways: The hot milk could be held in the bottles at 145° F. instead of in a tank, and the crates of hot pasteurized milk could be cooled by spraying with cold water instead of air.

From a sanitary point of view the important advantage of the process of bottling hot pasteurized milk in hot bottles lies in the fact that bottle infection is eliminated, and if the bottles of hot milk can be cooled successfully by forced-air circulation, the process of pasteurization would be raised to its highest state of efficiency by relatively simple methods.

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BULLETIN No. 421

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L. O. HOWARD, Chief

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THE SUGAR-BEET THRIPS.[1]

By WM. H. WHITE, *Scientific Assistant, Truck Crop and Stored Product Insect Investigations.*

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INTRODUCTION.

During the winter of 1916 the sugar-beet thrips (*Heliothrips femoralis* Reuter) was found in large numbers in a greenhouse at Washington, D. C. While attacking a variety of plants, the insect confined itself principally to sugar-beet seedlings. Although long recognized as a greenhouse pest, the sugar-beet thrips occurs out of doors in some localities and is recorded as having a large number of food plants. Short notes on its injurious habits have been recorded and published from time to time, but as far as known the life history and habits of the immature stages hitherto have not been fully determined.

GENERAL DESCRIPTION.

In color this species is dark brown or black, the head, prothorax, and the end of the abdomen being reddish yellow. The eyes are dark brown. The forelegs are yellow, the middle and posterior pair yellow with brown femora or thighs. The wings are dusky, the posterior pair lighter, crossed by a white band at the base and a white band about two-thirds the distance from the base; the tips are white. The antennæ are three times as long as the head. The total length is about 1.3 millimeters.

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[1] The writer wishes to express his appreciation to Dr. F. H. Chittenden, under whose direction this work was conducted, for many helpful suggestions, and to Mr. J. D. Hood, for furnishing many references to literature pertaining to this subject.

HISTORY.

The sugar-beet thrips was first described by Prof. O. M Reuter (1),[1] from specimens taken in the greenhouse in 1891, at Helsingfors, Finland. The first record we have of its occurrence in the United States was made by Mr. Theo. Pergande (2), who described it in 1895 as *Heliothrips cestri* n. sp., and wrote that it had been known to him since 1884, at which time specimens were presented by Mr. P. B. Mann, who discovered them infesting a plant of *Cestrum nocturnum* from Massachusetts. He also stated that about the same time it was sent to him from Helsingfors, Finland; and that in 1883 he discovered the same species, extremely abundant on leaves of an amaryllis, in a conservatory of the Department of Agriculture at Washington, D. C. It was redescribed by Uzel in 1895 (3), and again by Hinds in 1902 (6). Since that time we have brief records of its occurrence in many localities in the United States and elsewhere.

DISTRIBUTION.

The sugar-beet thrips is widely distributed and is found principally in greenhouses. It is recorded as occurring in greenhouses in the British Isles, Italy, Belgium, Austria, Finland, German East Africa, Sweden, and Spain.

It is also well distributed over the United States, and is reported from the District of Columbia; Lacrosse, Wis.; Ithaca, N. Y.; Vienna, Va.; Urbana, Ill.; Champaign, Ill.; Lincoln, Nebr.; and Amherst, Mass.

The first observation which we have of its occurrence on sugar beets and out of doors was made by Dr. F. H. Chittenden (7), who collected specimens at Washington, D. C., on August 15, 1904. He also observed it on greenhouse sugar beets. In 1907 it was collected on sugar beet at Hamilton City, Cal., by Prof. E. S. G. Titus, and in 1914 from Rio Piedras, Porto Rico, on sugar cane, by Mr. Thomas H. Jones (Hood, 16).

FOOD PLANTS.

The sugar-beet thrips has confined itself chiefly to plants grown in the greenhouse, but it has been taken out of doors on sugar beets (Beta) and sugar cane (*Saccharum officinarum*). Hinds in 1902 listed the following food plants: *Amaryllis* sp., Aralia, calla (Arum), the night-blooming Jessamine (*Cestrum nocturnum*), Chrysanthemum, Crinum, cucumber (Cucumis), Dracaena, Amazon lily (*Eucharis grandiflora*), India-rubber tree (*Ficus elastica*), *F. grandiflora*, Gardenia, cotton (Gossypium), Hydrangea, *Mina lobata*, moon flower (*Ipomoea bonanot*), screw pine (Pandanus), date palm (Phoenix);

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[1] Figures in parentheses refer to Bibliography, p. 11.

yellow calla (*Richardea aethiopica*), tomato (Lycopersicum), and grape (Vitis).

The writer has also found it on Begonia, spinach (Spinacia), sweet potato (*Ipomoea batatas*), string beans (Phaseolus), and Mexican tea (*Chenopodium ambrosioides*).

EXTENT AND NATURE OF INJURY.

The injury caused by the sugar-beet thrips is similar to that of the other species of thrips of the group. The plant is attacked by the adult and nymphs in the same manner. The leaf cells are pierced, and the plant juices withdrawn, causing the cells to shrivel and turn white. When a number of these cells are destroyed they appear as irregular white or light-brown spots. If the attack is severe, the whole leaf surface becomes invested by these spots and finally shrivels and dries. The nymphs also render the plant unsightly through the brown watery excretion from the alimentary tract, which discolors the leaves.

Plate I shows a leaf of Swiss chard attacked by this thrips.

HABITS OF NYMPHS OF FIRST AND SECOND STAGES.

When ready to emerge, the young nymph breaks through the thin eggshell and pushes its way upward until all but the last abdominal segment is free. It remains upright and supported by the last segment until the appendages which are folded beneath the body unfold and become sufficiently hard for use. The forelegs are the first to unfold, followed by the middle and hind pair. The antennæ are now brought forward. The nymph then places its legs on the surface of the leaf and by constant pulling frees the body. A period of from 20 to 25 minutes is required for complete emergence.

The newly-hatched nymphs crawl about for a short time before commencing to feed. They usually collect and feed in colonies on the underside of the leaf, but if food is not abundant, both sides are attacked. Shortly after feeding, the body becomes discolored by the ingested food. The watery excretion from the alimentary tract is collected as a globule, which extends over the entire body except the head, and increases in size until it becomes too large to carry. It is then dropped and spreads over the leaf, giving it an unsightly appearance. The older nymphs are very active and when disturbed move rapidly, with the tip of the abdomen extended upward.

When full grown, the nymph seeks a secluded spot in which to transform. The curled portions of dead leaves form a favorite place of concealment, although the base of the plant and the portion of the leaves along the midribs may be selected.

HABITS OF NYMPHS OF THIRD AND FOURTH STAGES.

The nymphs of the third and fourth stages congregate at some isolated portion of the plant, as along the midribs, at the base, or among the dead or dying leaves (fig. 1), where they remain during transformation. When the attack on the plant has been severe, they will be found more often among the dead leaves.

The third-stage nymph remains practically motionless unless disturbed, when it becomes active and moves rapidly. While at rest it is flattened against the leaf surface.

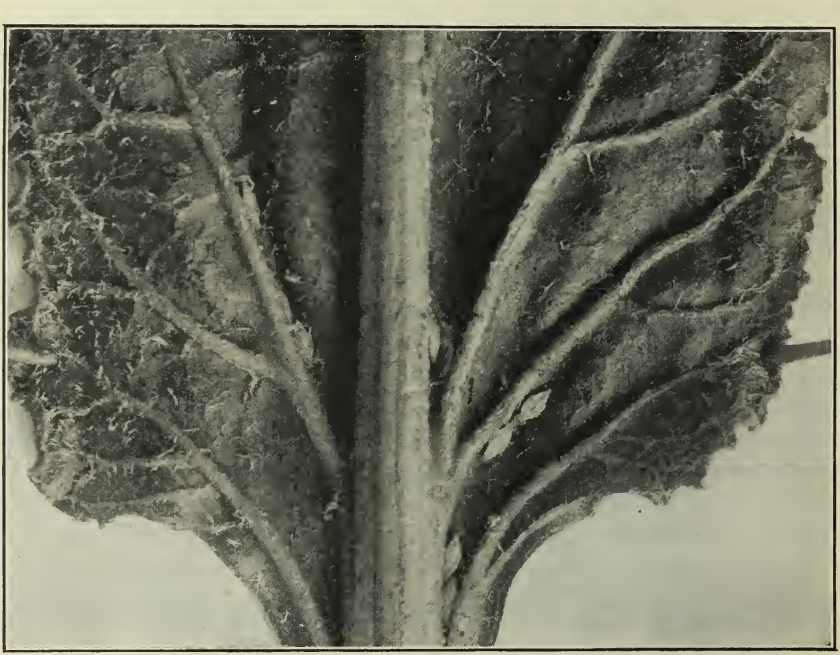
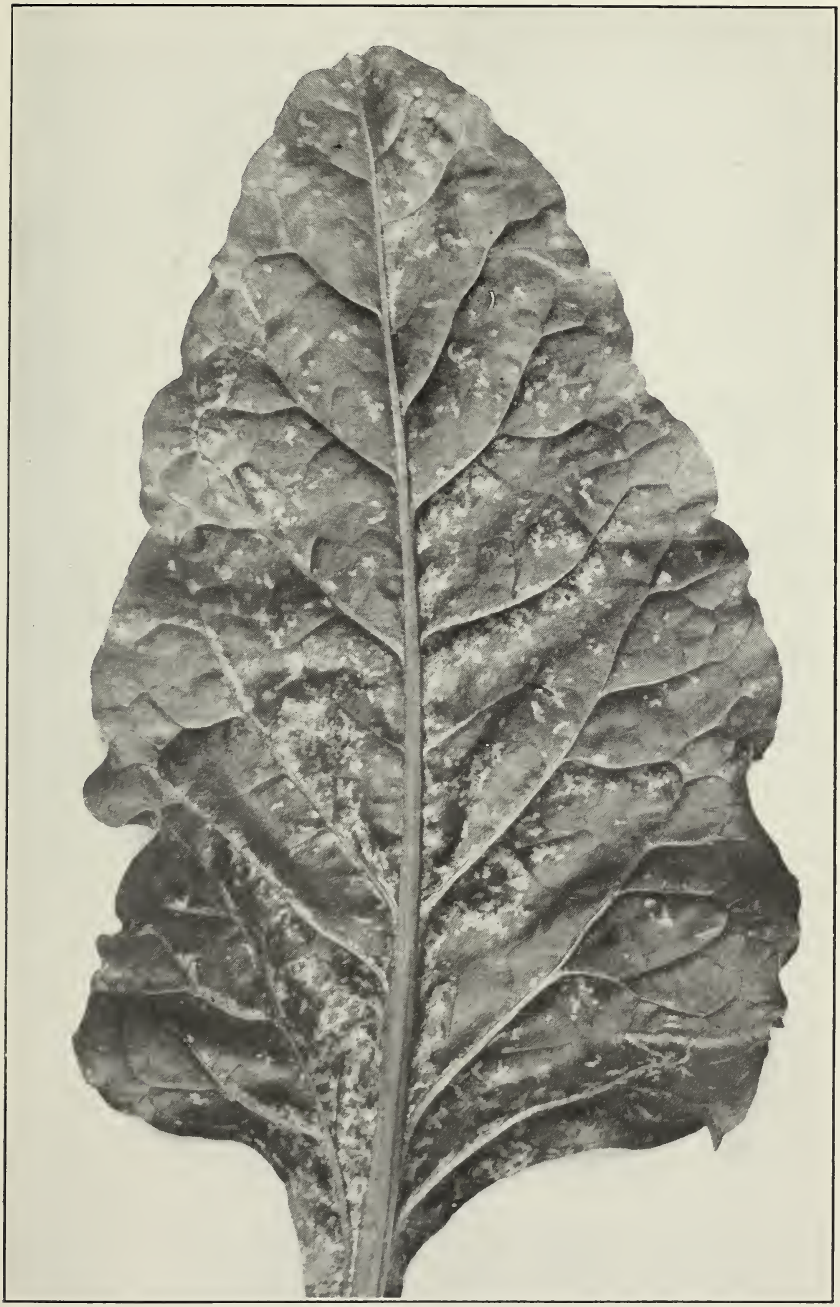


FIG. 1.—The sugar-beet thrips (*Heliothrips femoralis*): Section of sugar-beet leaf showing fourth-stage nymphs along midribs. Enlarged. (Original.)

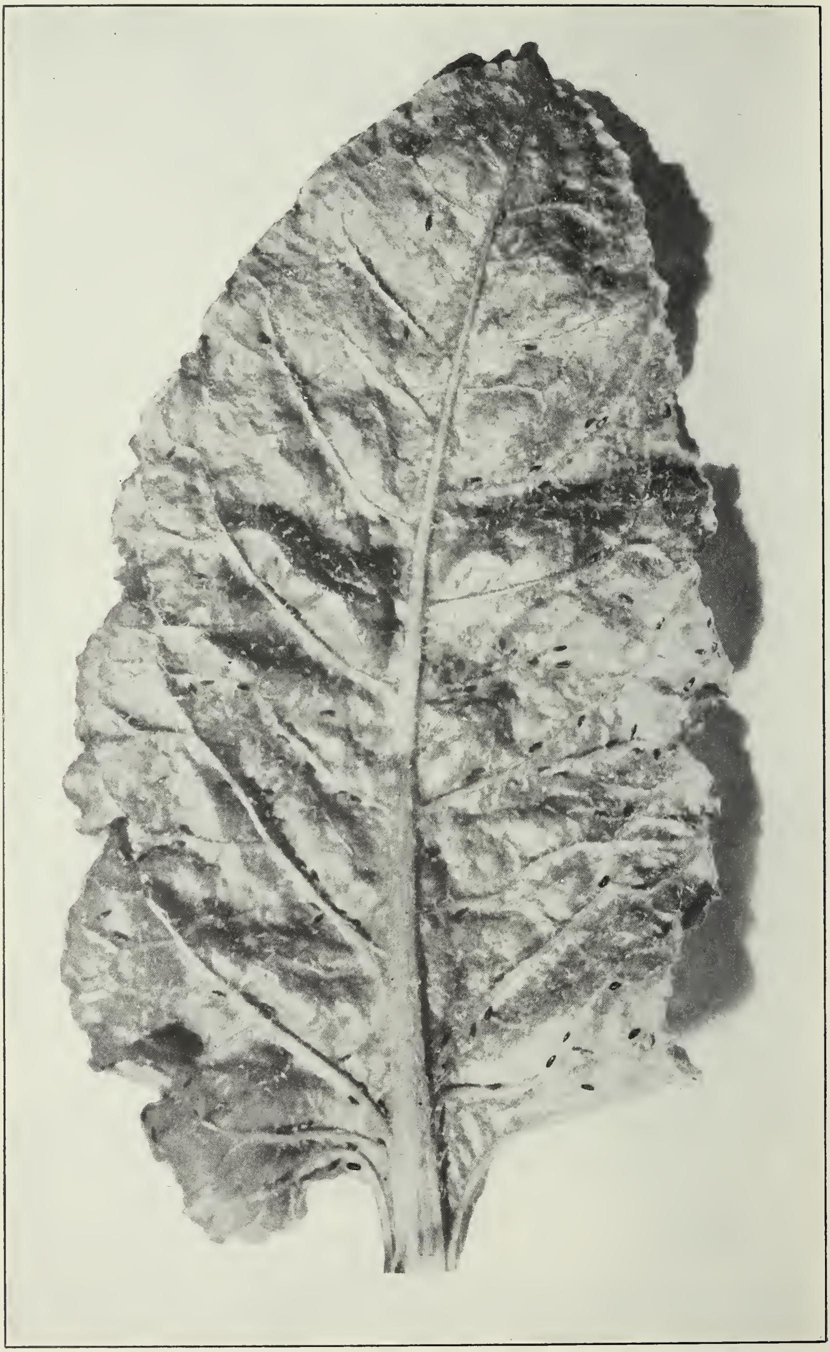
The nymph of the fourth stage remains motionless and in the same position as in the preceding stage. It is not so active, moving sluggishly and only for a short distance when disturbed.

HABITS OF THE ADULT.

When the adult emerges from the pupa case it is light yellow and very delicate, but as it hardens it gradually assumes its characteristic normal dark brown or black. It remains for a short period in the spot where it transformed before seeking food. As in the mature stages, nourishment is obtained by puncturing the leaf cells and withdrawing the plant juices, the adult apparently requiring less food than the nymph. While resting it remains flattened against the leaf surface along the veins and other parts of the plant. It crawls slowly



WORK OF THE SUGAR-BEET THRIPS (HELIOTHRIPS FEMORALIS) ON SWISS CHARD. (ORIGINAL.)



LEAF OF BEET SHOWING ADULTS OF SUGAR-BEET THRIPS. (ORIGINAL.)

about on the leaf with the abdomen curved downward, but if disturbed moves rapidly away with short, quick leaps. It seldom takes wing, although the writer has twice observed flight for a short distance.

A beet leaf showing the adult at rest is illustrated in Plate II.

The adult males are smaller and more active than the females, which usually greatly outnumber them, although at times the proportion becomes nearly equal. Copulation takes place during the day, as has been observed on a number of occasions.

Oviposition usually takes place at night or in the evening, but has been observed late in the afternoon.

DESCRIPTIVE.

THE EGG.

Egg (fig. 2) translucent white; surface without sculpture; elongate reniform, slightly flattened at cephalic end. Average length 0.249 mm.; width 0.108 mm. Deposited usually on the underside, obliquely to the surface, and beneath the epidermis of the leaf or stem.

When the embryo begins to develop, the egg becomes swollen and turns dull white.

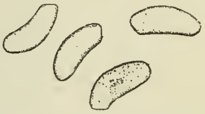


FIG. 2.—Eggs of sugar-beet thrips. Enlarged. (Original.)

THE NYMPH.

First stage (fig. 3).—Fusiform, translucent white; head, eyes, legs, and prothorax large in proportion to the rest of the body; length 0.481 mm.

Head subquadrate; slightly rounded in front. Length 0.083 mm.; width at eyes 0.103 mm. The eyes dark red, ocelli absent. Antennæ, length 0.249 mm.; the segments confused with the exception of 2 and 3, which are separate; segments 1 and 2 cylindrical, bearing spines on outer margins; segment 2 slightly longer; segment 3 pedunculate, annulate, bearing spine on outer anterior margin; segment 4 fusiform, annulate, nearly twice as long as 3, bearing two spines on upper margin; segments 5, 6, 7, and 8 slender and tapering toward apex; spine on outer margin of segment 5. The head bears two pairs of setæ dorsally, and one in front of the eye on the outer margin. Prothorax large, transverse, rounded at the margins, bearing one pair of setæ on lateral margin; length 0.09 mm.; width 0.146 mm. Mesothorax, width 0.398; mesothorax and metathorax each bear a pair of setæ on outer margin, and one pair dorsally. Legs translucent, robust, bearing numerous short spines. Abdomen tapering posteriorly, segments subequal in length, with the exception of 9 and 10, which are longer; 9 about half as long as 10. Each segment, except 9 and 10, bears three pairs of setæ; one pair on the lateral margin, and two on the dorsum; segments 9 and 10 bear 2 pairs. The mesothorax and segments 2 and 8 of the abdomen each bear a pair of spiracles.

Second stage (fig. 4).—Body fusiform, translucent, tinged with faint yellow. Length 1.41 mm.

Head subquadrate, rounded and narrowed in front; about as wide as long; length 0.099 mm.; width 0.133 mm. at eyes. Antennæ 8-jointed, all segments distinct except 7 and 8, which do not appear to be movable; segments 3, 4, 5, 6, and 7 annulate. Length 0.332 mm. The prothorax transverse, narrowed toward the head; width 0.294 mm.; length 0.149 mm. Mesothoracic angles prominent; width of mesothorax

0.315 mm.; one pair of setæ on each lateral margin of the prothorax, and one on the posterior margin; two pairs on the dorsum of the mesothorax and metathorax.

Abdomen tapering gradually posteriorly until the ninth segment, then abruptly. Segments 9 and 10 much narrower than the rest and bearing the rudiments of a pair of obtuse spines on the posterior margins. The first abdominal segment bears one pair of lateral setæ; segment 9, one pair dorsally and one laterally; segment 10 bears one pair; the remaining segments bear two pairs dorsally and one pair laterally.

Third stage (fig. 5).—Head subquadrate, wider than long; length 0.116 mm.; width 0.166 mm. Eyes dark red, small; ocelli absent. Antennal cases, segments confused; only five apparent; length 0.265 mm.

Prothorax transverse, half as long as broad; length 0.133 mm.; width 0.266 mm.; a row of setæ on the lateral and posterior margins. Mesothoracic angles prominent; width of mesothorax 0.299 mm. The wing pads reach to the third abdominal segment. Length of wing pads from the base to the tip 0.299 mm.; the hind pair the longest. Abdomen fusiform, tapering slightly anteriorly; the last two segments are much narrower than the rest, and bear on their posterior margins two large obtuse spines, which extend upward.

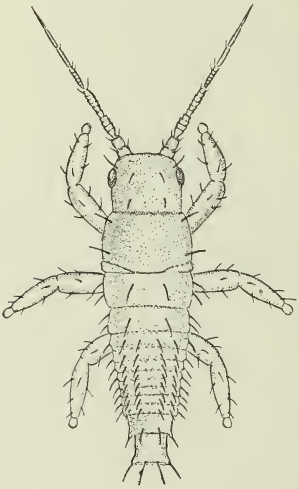


FIG. 3.—Newly-hatched nymph of sugar-beet thrips. Enlarged about 160 diameters. (Original.)

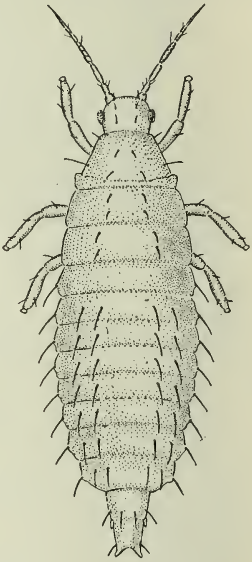


FIG. 4.—Second-stage nymph of sugar-beet thrips. Enlarged about 40 diameters. (Original.)

Fourth or last stage (fig. 6).—Color translucent white; length 1.469 mm.

Head subquadrate, faintly reticulate; wider than long; length 0.12 mm.; width 0.199 mm. Eyes dark red; three ocelli present, lighter in color than eyes. Antennal cases folded back over the head, the apices extending to the middle of the prothorax, the cases coming in contact beyond the middle of the head. Segments confused; 1 and 2 protruding in front of the head. Segment 2 bears four setæ, two long and two short ones, extending forward. The head bears four setæ, one behind each eye and two small ones between the antennal cases. The newly formed antennæ may be seen through the wall of the case

Prothorax transverse, about three-fourths as wide as long; length 0.158 mm.; width 0.232 mm.; margins rounded; a row of setæ extending around the margins, with the exception of the anterior margin. Mesothoracic angles prominent and acute; width 0.282 mm. Wing pads extend to the middle of the fifth abdominal segment, each forewing pad bearing 12 to 13 short spines; length of wing pad from base to apex 0.564 mm.

Abdomen fusiform, tapering slightly anteriorly; segments 9 and 10 much narrower than the rest, each bearing a pair of large obtuse spines, which extend upward. Each segment except 1, 9, and 10 bears two dorsal pairs of setæ, one placed laterally and one sublaterally. The first segment is without setæ, and 9 bears two pairs on lateral margin; 10 bears only one pair.

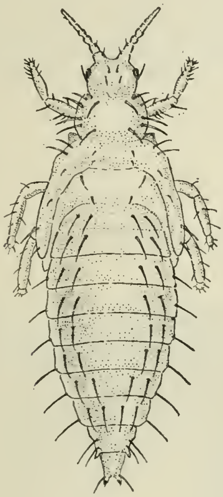


FIG. 5.—Third-stage nymph of sugar-beet thrips. Enlarged about 40 diameters. (Original.)

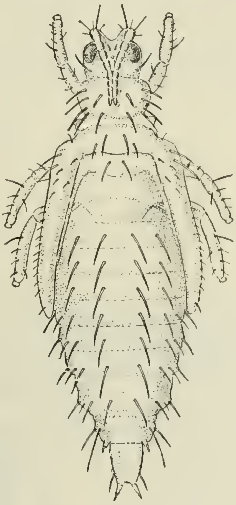


FIG. 6.—Fourth-stage nymph of sugar-beet thrips. Enlarged about 40 diameters. (Original.)

Legs translucent white, bearing numerous short spines, with one long spine on the tibiæ.

THE ADULT.

The adult female (fig. 7) is described by Hinds as follows:

HELIOTHRIPS FEMORALIS REUTER.

Female.—Length 1.3 mm. (1.12 to 1.5 mm.); width of mesothorax about one-fourth the body length. General color dark brown to yellowish brown, lighter at extremities. Entire surface of body weakly but plainly reticulated.

Head two-thirds as long as broad, widest in front; anterior margin depressed at insertion of antennæ; vertex carinated; bases of antennæ separated by a prominence as high and nearly as wide as the first antennal segment; two transverse wrinkles near back of head more prominent than the others; behind the anterior one of these two the longitudinal parts of the reticulations become very faint; spines upon head scattering and small. Eyes quite large, protruding anteriorly, coarsely granulated; eyes and margins of ocelli bright, dark red by reflected light; ocelli placed on sides and front of a distinct elevation on top of head between eyes. Head light brown with light yellowish longitudinal stripe on each side between eye and ocelli. Maxillary palpi three-segmented, short, small; labial palpi minute. Antennæ eight-segmented, slender, nearly three times as long as head; relative lengths of segments as follows:

1	2	3	4	5	6	7	8
5	8.8	16.6	12.2	11	8.6	4.3	10.5

Segment one cylindrical, three-fourths as broad as two, which is barrel-shaped and annulated; remaining segments narrower than these two and more elongated; three and four fusiform; seven and eight nearly cylindrical; eight very slender; one, two, and three nearly concolorous, light yellow with tinge of gray or brown on one and two; four and five light yellow in basal half, shading to light brown on apical half; six, seven, and eight uniformly chocolate brown; segments two to five annulated; spines slender, light colored.

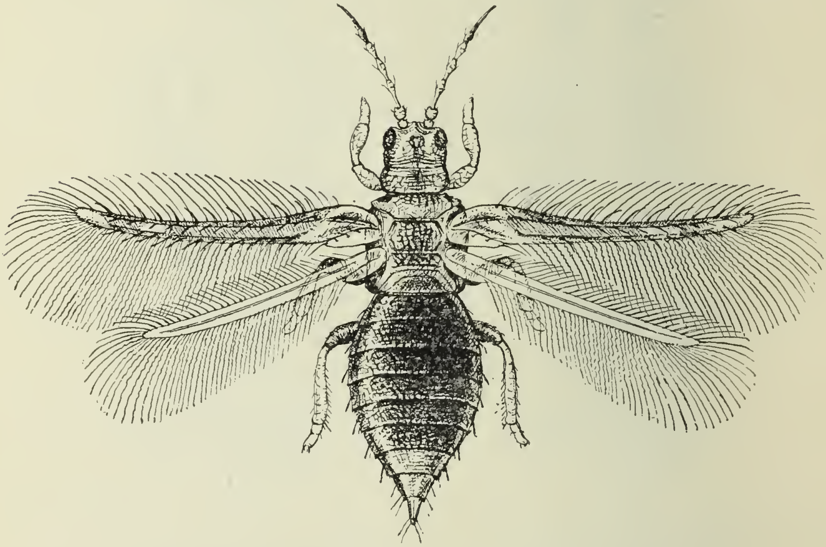


FIG. 7.—Adult female of sugar-beet thrips. Enlarged. (Original.)

Prothorax transverse, about one-fifth wider than the head, twice as wide as long and shorter than the head; sides rounded; without conspicuously large spines. Mesothorax about one and two-thirds times as wide as the head; anterior angles prominent; mesonotum with deep incision on posterior margin; metanotum with four spines standing in a square near its center. Wings present, long, about one-sixteenth as broad as long; fore wings broadened at base, with two longitudinal veins, the second branching from the first not far from the base of the wing. Spines upon veins of fore wing stout, dark colored, and set at uniform distances; costa bears seventeen to twenty, fore vein fourteen to seventeen, hind vein ten to thirteen, scale three to five besides pair at its tip; spines on basal fourth of wing are light colored, smaller, and much less conspicuous; anterior fringe on both wings fairly long and stout; posterior fringe long, slender, and dark colored. Wings grayish brown to dark gray, lighter between the longitudinal veins; three nearly white cross bands; one across base before branching of veins, another at three-fourths the length of wing and the third across the tip. Legs: All tibiæ, tarsi, and fore femora yellow; middle and hind femora dark brown, yellow only at ends; spines upon legs small and inconspicuous except ten to twelve on inner side of hind tibiæ.

Abdomen broadly ovoid, conical at tip, twice as wide as head; ovipositor long and slender; tenth segment split open above; segments two to eight with dark cross line near anterior edge. Two or three spines on sides of each segment from two to eight, not conspicuous; anal spines weak. Color of abdomen yellowish brown to dark brown; last two segments much more yellow, but shading to brown at posterior edges.

This species has the power of springing.

A description of the male, which hitherto has not been recognized, is appended.

Male.—The male resembles the female in appearance, but is much smaller and more active. The abdomen tapers gradually posteriorly; the apex (fig. 8) is truncate; the last segment is short and broad. Segment 9 bears dorsally three pairs of short, black, obtuse spines, light brown at the base; two pairs near the middle of the segment, and one pair near the posterior margin, and more widely separated.

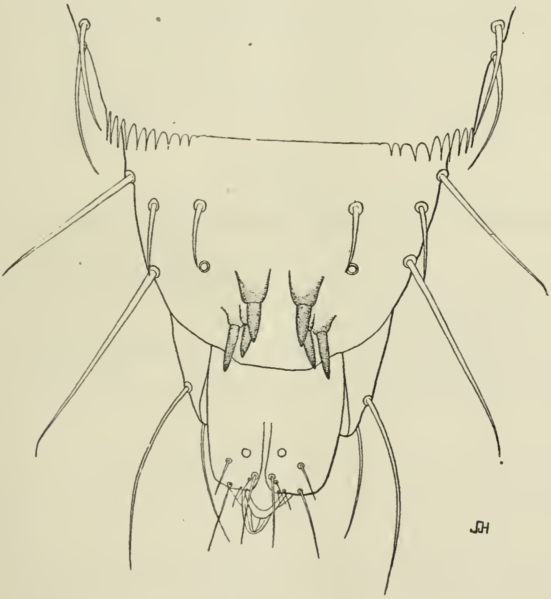


FIG. 8.—End of abdomen of male of the sugar-beet thrips. Greatly enlarged. Drawn by J. D. Hood. (Original.)

Measurements: Length of head 0.099 mm.; width of head 0.174 mm.; width of prothorax 0.199 mm; length of prothorax 0.0996 mm.; width of metathorax 0.282 mm.; width of abdomen at third segment 0.299 mm.; length of abdomen 0.73 mm.; length of antennæ 0.299 mm. Total length 1.185 mm.

LIFE CYCLE.

The life history was determined under natural greenhouse conditions. Females were isolated on small beet seedlings, and as soon as they deposited eggs the adults were removed. The temperature and moisture were fairly constant, the maximum temperature being reached in the middle of the day. The average mean temperature was about 73° F. during the time of development.

The egg requires from 12 to 14 days to develop; the nymph molts four times, the first instar lasting about four days. The second stage transforms to the third in about eight days. The third stage is short, the skin being molted in about a day. The fourth or last stage requires about five days before it emerges as an adult.

The full length of the adult's life was not determined, but adults emerging from isolated pupæ on February 11, 1916, were still alive 40 days later.

The normal mode of reproduction is bisexual, but owing to the fact that at certain intervals the proportion of males to females is very small, it is likely that parthenogenesis occurs as in other species of this group. While this species was under observation males were present most of the time, but in very small numbers, although on one occasion they appeared very abundant, nearly equaling the females.

CONTROL.

In the greenhouse the sugar-beet thrips may be held in check by the application of a strong spray of water to the foliage. This washes the younger stages from the leaf; and as these are unable to reach the food plant again, they die.

As a result of experiments, spraying is the best method of control, both in the greenhouse and out of doors. The following solutions were used:

Experiment No. 1.

Nicotine sulphate	ounces	4
Fish-oil soap	pounds	4
Water	gallons	50

Result: About 60 per cent of adults and 40 per cent of nymphs killed.

Experiment No. 2.

Nicotine sulphate	ounces	5
Fish-oil soap	pounds	4
Water	gallons	50

Result: Ninety per cent of adults and 60 per cent of nymphs killed.

Experiment No. 3.

Nicotine sulphate	ounces	6
Fish-oil soap	pounds	4
Water	gallons	50

Result: All adults and about 95 per cent of nymphs killed.

The fact that the adults were more susceptible to the spray than the nymphs may be due to the globule of excretion which serves to protect the body of the nymph.

The spray should be applied to both sides of the leaves; if possible, on a dull or cloudy day. The adults are not so active at this time and are, therefore, less likely to move out of reach of the spray.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 422

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER October 2, 1916

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THE EGGPLANT TORTOISE BEETLE.

By Thos. H. Jones,
Entomological Assistant, Truck-Crop and Stored-Product Insect Investigations.

INTRODUCTION.

During the spring of 1915 the larva of a tortoise beetle, *Cassida pallidula* Boh., was observed in injurious numbers on the foliage of young eggplant and on the leaves of Irish potato at Baton Rouge, La. While injury to eggplant by this species was mentioned by Riley, under the name of *Cassida texana* Cr., as early as 1882 (2),[1] and while other writers have referred to its presence on wild Solanums, no comprehensive article regarding it has been published. During 1915 the writer, assisted by Mr. C. E. Smith, of the Bureau of Entomology, kept the insect under observation at Baton Rouge, La., studying its life history and habits and conducting control experiments with insecticides. Although the species has not been found to be a pest of first-class importance to the plants which it attacks, it is apparent that it is, at times at least, destructive enough to its cultivated hosts to warrant the use of insecticides for its control.

DISTRIBUTION.

The species is somewhat widely distributed over the more southern portions of the United States. Riley (2) has recorded it from southern Texas and Washington, D. C., Coquillett (4) reported its presence in California, and Blatchley (6) lists it in his "Coleoptera of Indiana." It also occurs in Missouri, Kansas, Oklahoma, New Mexico, and Arizona (7, 8).

HOST PLANTS.

Riley (2, 3) has recorded it as feeding on *Solanum elaeagnifolium*, *S. carolinense*, and eggplant, and Coquillett (4) found it on *Solanum xanti* in California. Wickham (5) has stated that he saw it feeding on Solanum in the lower Rio Grande Valley. At Baton Rouge, La., it has been found on *Solanum carolinense*, eggplant, and Irish potato.

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[1] Figures in parenthesis refer to "Bibliography," p. 8.

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DESCRIPTION.

THE EGG.

The egg (fig. 1) is ellipsoidal in shape and creamy white when first deposited, later becoming brownish. Ten eggs gave an average length of 1.24 mm., ranging from 1.16 to 1.30 mm., and an average width of 0.67 mm., ranging from 0.62 to 0.76 mm.

THE FIRST-STAGE LARVA.

The general color is greenish white, with light, dirty brown head, and with the tips of the mandibles and the claws dark brown. The head and legs are large and out of proportion to the rest of the insect. The surface of the body is sparingly covered with short spines. Sixteen pairs of branched appendages extend from the sides of the body, the branches being larger on the anterior pair. Another pair of long appendages originates on the dorsal surface of the body, just anterior to the anus, and it is upon this pair that the excrement and cast skins, commonly known as the "pack," are carried, the pair of appendages sometimes being called the "fæcifork." The length of the first-stage larva, including the head, is about 1.5 mm. and the width of the head about 0.46 mm.

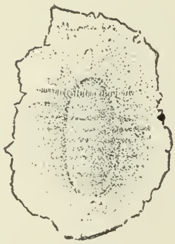
FIG. 1.—Eggplant tortoise beetle (*Cassida pallidula*): Egg. Greatly enlarged. (Original.)

THE SUCCEEDING LARVAL STAGES.

There are in all five larval stages. The principal difference between them is the increase in size after each molt, the full-grown larva measuring from 5 to 5.5 mm. in length.

There is some variation in the position of the appendages along the sides of the body in the various stages. After the first molt the head and legs are smaller in comparison with the growth of the body and are not so conspicuously out of proportion as in the first instar. The color of the body in the second and in the succeeding stages is light green, sometimes tinged with yellow. The cast larval skins of the various stages are often retained on the fæcifork up to the time the larva is ready to transform to the pupa. They are arranged consecutively, that of the first nymphal stage nearest the tip of the fork and with the head molts on the upper surface of the pack as it is held over the dorsal surface of the body.

The width of the heads of individuals in any one stage is quite constant, that of the second instar being about 0.55 mm., that of the third about 0.67 mm., that of the fourth about 0.82 mm., and that of the fifth about 0.97 mm.

THE PUPA.

The fringe of appendages persists in the pupa, there being five branched pairs on the sides of the abdomen and about 45 smaller appendages around the edge of the prominent thoracic shield. The antennæ, legs, and wings of the adult are evident on the ventral surface, held against the body. Portions of the larval molts adhere to the blunt tip of the abdomen, by which the pupa is attached to the surface upon which it rests.

Measurements of five individuals gave an average length of 5.4 mm., the length varying from 5 to 5.5 mm. The average width of the thoracic shield was 2.9 mm.

THE ADULT.

The following description of the adult (fig. 2.) is taken from Blatchley (6):

> Oblong-ovate, sides nearly parallel. Uniform dull green or greenish-yellow; antennæ with last three joints piceous. Thorax twice as wide as long, the angles all broadly rounded; margin very broad, flat and translucent. Elytra with humeral angles prominent, margins broadly flattened, punctures very coarse and close-set; intervals narrow. Length 5–5.5 mm.

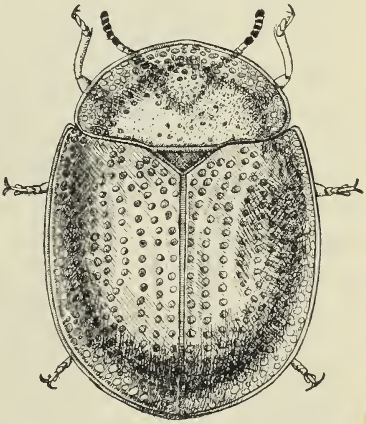

FIG. 2.—Eggplant tortoise beetle: Adult. Enlarged. (Original.)

DEVELOPMENT.

OVIPOSITION.

On eggplant the greater number of the eggs have been found on the underside of the leaves, although they are also placed on the surface and sometimes on other portions of the plant. While as many as four eggs have been found together, they are usually placed singly or in groups of two or three eggs each. Where more than one egg occurs they are placed one above another. Surrounding the egg and extending from it in the plane of its greatest circumference, to form a more or less rectangular flake, is a thin, transparent layer of membranous substance having a brownish tinge. Covering this, almost without exception, is a second, larger flake of the same material. These are attached to each other at the end where the flake inclosing the egg is attached to the surface upon which it is placed.

Eggs were first noted in the field at Baton Rouge, La., on May 11 and were present as late as September.

PERIOD OF INCUBATION.

During June the period of incubation of eggs kept in the insectary was quite constant, the larvæ issuing in from four to five days after the eggs had been deposited.

The following table gives the mean maximum and minimum temperatures for the insectary where the life-history studies were conducted, and the corresponding figures given for Baton Rouge by the United States Weather Bureau. Readings were taken each morning from a maximum and minimum thermometer.

TABLE I.—*Mean maximum and minimum temperatures at Baton Rouge, La., during June, July, and August, 1915, when life-history studies on eggplant tortoise beetle were conducted.*

Period.	U. S. Weather Bureau, mean temperatures.[1]		Insectary, mean temperatures.		Excess of mean insectary temperatures over those of U. S. Weather Bureau.	
	Max.	Min.	Max.	Min.	Max.	Min.
	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
June	91.5	72.3	94.9	73.9	3.4	1.6
July	92.5	71.9	95.4	74.8	2.9	2.9
August	91.3	70.0	92.1	74.0	.8	4.0

[1] Climatological data, Louisiana section, for months of June, July, and August, 1915, by Isaac M. Cline, pp. 46, 54, 62, New Orleans, La., 1915.

LENGTH OF LARVAL PERIOD.

The length of the larval period has been found to vary greatly in the insectary. Forty-three larvæ that were kept under observation during June and July required from 12 to 20 days to develop, 17 days being the average. No satisfactory reason for this wide difference can be suggested. Larvæ that issued on the same day and which were apparently kept under similar conditions pupated, in some cases, six days apart. On eggplant grown under cages out of doors the larval period was completed in 12 days during June.

The larvæ are sluggish and occur on both sides of the leaves, in which they eat more or less circular holes. When the larvæ are young these holes are small in size, but with the growth of the individual there is an increase in the quantity of tissue removed.

LENGTH OF PUPAL STAGE.

The pupal period occupied from two to seven days in the insectary during June and July, though most of the individuals remained in the pupal stage from four to five days.

LIFE AND HABITS OF ADULTS.

The adults, even during the summer, live for a period of several weeks. In the insectary one individual, a female, was kept alive from May 22 to October 9, two months after it had ceased to lay eggs, and others have lived for two or three months. The winter months are undoubtedly passed in the adult stage.

The injury done to the leaves of eggplant (fig. 3) by the adults is of the same character as that due to the larvæ, the feeding of the beetles producing holes which are somewhat circular in outline.

NUMBER OF EGGS DEPOSITED BY ONE FEMALE.

On July 4, beetles that had issued in rearing cages in the insectary, none of which had begun to oviposit, were placed together on eggplant leaves. The first eggs were noted on July 6, when the beetles were separated, except for a pair that was found copulating. The next day it was found that three females of this lot had deposited eggs, and these individuals were placed on eggplants growing in flowerpots. One of them was the female with which the male beetle had been placed and the male was kept with the female until the latter died. The eggs were removed each day and counted. The female which was paired with the male completed egg laying sooner than did the others, although it did not deposit as many eggs as did one of the isolated females. Toward the end of the period of oviposition a few objects, apparently eggs without the surrounding membrane, were noted on the leaves in the cages with the isolated female beetles. Larvæ failed to develop from these, however, and they were

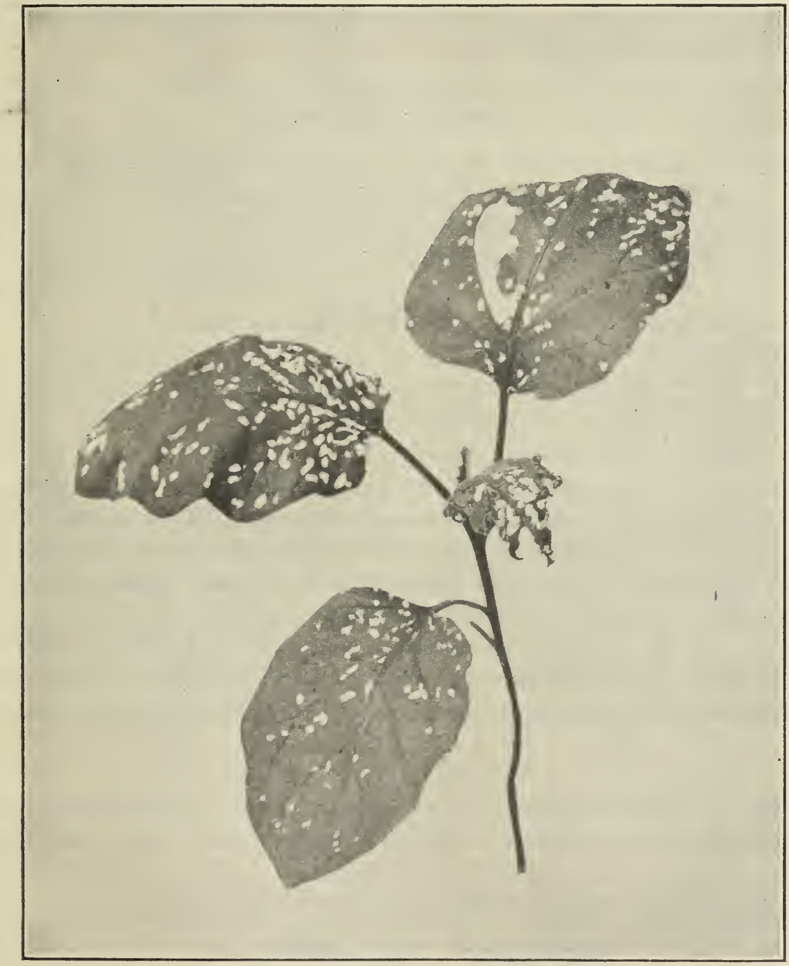

FIG. 3.—Young eggplant showing injury by the eggplant tortoise beetle. Reduced. (Original.)

not counted as eggs. The following data have been selected from the data concerning these three females:

TABLE II.—*Egg-laying records of three females of the eggplant tortoise beetle.*

	Female A.	Female B.	Female C.
Egg laying begun	July 7	July 7	July 7.
Last eggs deposited	Aug. 16	Aug. 26	Aug. 24.
Total number of eggs deposited	268	269	231
Greatest number deposited in one day	10	12	11
Average number deposited in a day	7	5	5

NUMBER OF GENERATIONS.

With a continuous food supply available during the spring, summer, and fall, it is apparent that several generations, perhaps five, will develop during this time at Baton Rouge. The minimum life cycle in the insectary during June can be summed up as follows:[1]

	Days.
Period from appearance of first adult to date first eggs were laid	9
Length of egg stage	4
Length of larval stage	12
Length of pupal stage	2
Total	27

During the same period the egg and larval stages were completed in 16 days in outdoor cages, corresponding to the minimum time required in the insectary. As larvæ were observed in the field as early as May 10 and as late as October 20, there is a strong probability that, under ideal conditions, there may be five generations in a year. After the first generation, individuals in all stages are found in the field at the same time, so that it is hardly possible to determine the number of generations that develop under natural conditions.

ENEMY.

The only insect enemy of this tortoise beetle that has been found is an egg parasite which has not been determined as yet. So far as observed this species, which was first noted at Baton Rouge during August, destroys only a small percentage of the eggs.

EXPERIMENT WITH ARSENICALS.

During May larvæ were causing sufficient injury to small eggplant at Baton Rouge to warrant the application of poison to the plants, and an experiment with arsenate of lead and arsenite of zinc was conducted, the application being made with a compressed-air sprayer. From this experiment the following summary has been made:

---

[1] Somes (7) found in Missouri that from eggs laid in July a longer period was required for the development of a generation.

TABLE III.—*Results of arsenical sprays against the eggplant tortoise beetle.*

Treatment.	Number of larvæ on 25 plants before spraying.	Number of larvæ on same plants 2 days after spraying.	Number of larvæ on same plants 4 days after spraying.
Sprayed with arsenate of lead, powdered, at rate of 1 pound to 50 gallons of water	85	14	2
Sprayed with arsenite of zinc, powdered, at rate of 1 pound to 50 gallons of water	93	12	2

During this time there was no apparent decrease in the number of larvæ on unsprayed plants. It is apparent that the larvæ can be controlled satisfactorily by the use of an arsenical which might, at the same time, serve to lessen the injury caused by other leaf-eating insects. In transplanting eggplant in sections where this tortoise beetle is abundant it would be advisable to dip them in some spray mixture to prevent injury.

SUMMARY.

During 1915 a tortoise beetle (*Cassida pallidula* Boh.) was found injuring eggplant and Irish potato at Baton Rouge, La.

This species has hitherto been recorded as feeding on eggplant and various wild Solanums.[1] It is somewhat widely distributed over the southern United States.

The various stages have been described from life-history studies carried on at Baton Rouge.

Three females reared in the insectary deposited, respectively, 268, 269, and 231 eggs, one laying as many as 12 in one day, and another averaging 7 eggs a day.

The minimum life cycle in the insectary was found to be 27 days. Under ideal conditions it is possible that five generations may develop in the field at Baton Rouge during the spring, summer, and fall.

Only one enemy, an undetermined egg parasite, has been noted.

An experiment with arsenate of lead and arsenite of zinc indicates that the species can be controlled satisfactorily by the use of arsenicals.

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[1] Numerous observations have been made of this species and its occurrence on solanaceous plants, many of which have not been recorded. In 1903, June 12, it was observed at Riverview, Md., on wild Solanum. May 4, 1903, it was observed by Mr. J. C. Bridwell at Willis, Tex., on *Solanum carolinense.* He also observed this species on the same plant in Kansas in earlier years. May 8, 1908, and March 31, 1909, Messrs. McMillan and Marsh observed this species on *Solanum elaeagnifolium.* February 6, 1912, Mr. M. Beatty observed this species on potato and eggplant at New Orleans, La. During June, 1915, the species was observed on eggplant by Mr. F. B. Milliken, at Wichita, Kans. We have received specimens from Kansas City, Mo., and from Agricultural College, Miss., the latter collected by Mr. J. W. Bailey, on eggplant.—F. H. CHITTENDEN

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BULLETIN No. 423

OFFICE OF THE SECRETARY.
Contribution from the Office of Farm Management,
W. J. Spillman, Chief.

Washington, D. C. PROFESSIONAL PAPER November 25, 1916

LABOR REQUIREMENTS OF DAIRY FARMS AS INFLUENCED BY MILKING MACHINES.

By Harold N. Humphrey, *Scientific Assistant.*

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It is the object of this bulletin to present the results of studies of the organization of dairy farms, made with special reference to the economic status of the milking machine. The use of the mechanical milker directly affects farm organization through its bearing upon the amount and distribution of labor required by the farms. In general farming labor efficiency is secured by the production of crops in combination with such other farm enterprises as will provide a nearly uniform amount of work throughout the year. There is no constant determining factor as to labor requirements. On the farm which receives the major part of its income from dairy products, however, the dairy alone is generally the determining factor. Any marked saving of labor effected on such a farm must be made in the production or handling of milk, hence the significance of the milking machine as a factor in the organization of the dairy farm.

The data upon which this bulletin is based were secured from 109 New York dairy farms, 56 of which were using mechanical milkers, and from 160 dairy farms in Ohio, Michigan, and Illinois, of which 100 were using milking machines. On the New York farms dairying

Note.—This bulletin is of interest to dairymen generally, and especially to those having herds of over 15 head of cows.

constituted 90 per cent or more of the total farm business. The farms studied in Ohio, Michigan, and Illinois devoted considerable time to general farming as well as to dairying.

FACTS BROUGHT OUT.

The following is a brief summary of the more important facts developed by this study:

The time saved by the use of the mechanical milker increases with increase in the size of the herd.

With herds of 15 cows or less the average time required to milk a cow by hand is a fraction over 7 minutes; by machine a fraction under 5 minutes.

With herds of over 50 cows it takes slightly under 7 minutes to milk a cow by hand and but 4.15 minutes by machine.

With herds of over 50 cows one man with a machine milks on the average about 28 cows per milking as against 17 where the milking is done by hand.

With increase in the size of the herd the cost per cow of hand milking changes very little, while the cost per cow of machine milking decreases rapidly.

With herds of 15 cows or less the average cost of milking per cow by hand is $10.91 per year as against $10.45 in herds of 50 or more.

With herds of 15 cows or less the average cost of milking per cow by machine is $11.77 per year as against $7.34 for herds of 50 or over.

Although with the average small herd of 15 cows or less it costs more per cow to milk by machine than by hand, it does not follow that the machine is necessarily an unprofitable investment on all farms on which such small herds are kept. On 32 farms having herds of 15 cows or less the use of the mechanical milker was found to effect an annual saving in hired labor of $2.63 per cow through the dropping of hands who had been kept primarily to do the milking.

SOURCES OF DATA.

As is shown in figure 1, the dairy industry is very widely distributed over the United States. In its more intensive forms it is, however, confined to areas which are in close proximity to large cities. The extent of these areas is determined by the city market, the transportation facilities afforded, and the adaptability of the region to dairying. Thus we have, for example, New York City, which requires a large supply of fresh milk for daily consumption. In many sections the rough, hilly country of New York and New England is better adapted to the dairy industry than to other types of farming (see fig. 2). Transportation facilities have been perfected so as to enable the shipping of fresh milk from the extreme northern part

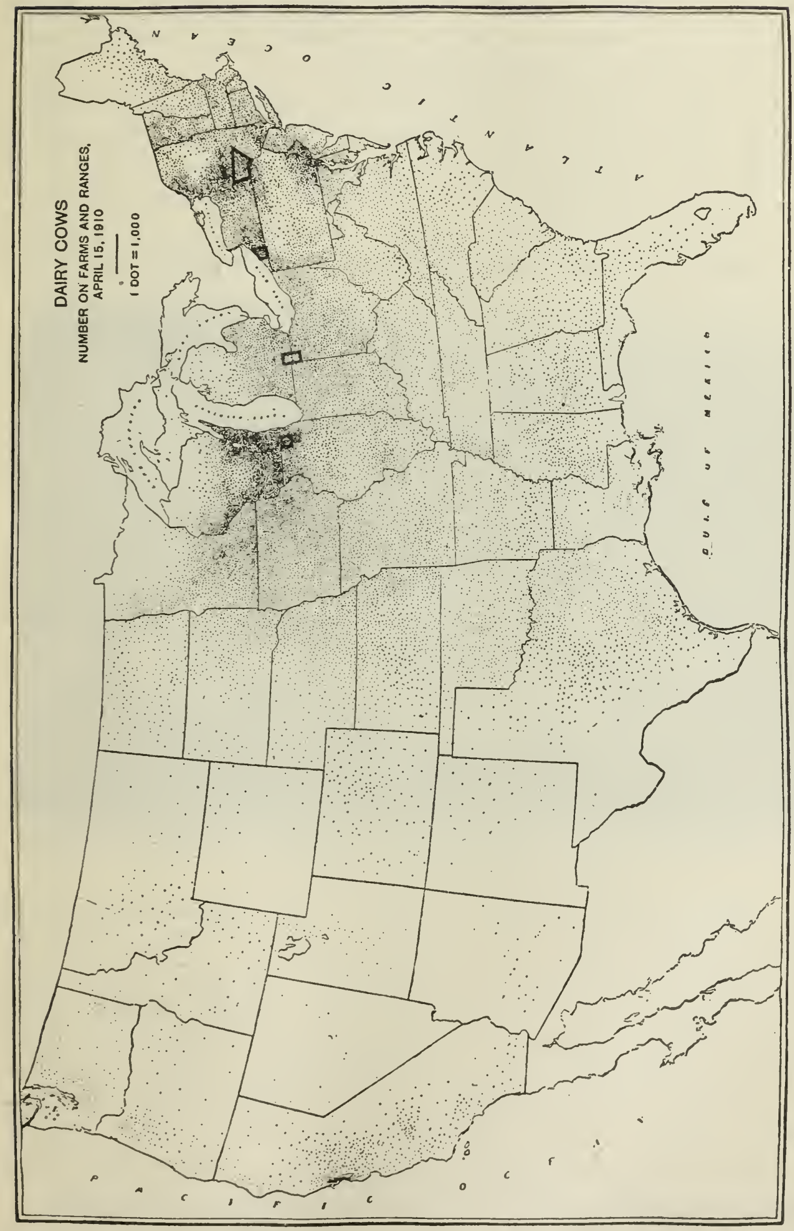

FIG. 1.—Map showing the distribution of dairy cows on farms and ranges in the United States. The areas in which data were obtained for this study are inclosed in heavy black lines.

of New York and as far west as the Finger Lake district. In this entire area all of the above three conditions—market, adaptability of the area to dairying, and transportation facilities—are present; hence there has been developed a most intensive form of the market milk industry. Boston may be cited as another city presenting similar conditions, but on a much smaller scale.

In no other part of the United States do like conditions obtain. The large cities of the Central West, it is true, offer a large market for fresh milk, but the natural, topographical, and soil conditions of the environing farming areas are more or less favorable to crop production; hence we find in these areas a less intensive type of dairying than we find in the more rugged country about the great cities of the East. Only in the immediate vicinity of the largest cities of the Central West is market milk produced intensively. Dairy farms located outside of this limited area receive a much smaller proportion of their income from dairy products than does the average dairy farm of the East. (See fig. 3.) It is from such farms that much of the butter and cheese made in the United States comes. The total value of Iowa's dairy products is great, yet the majority of Iowa farmers maintain comparatively small herds of dairy cattle. According to the Thirteenth Census, in 1909 this State ranked third in the production of butter, with Wisconsin first and Minnesota second.

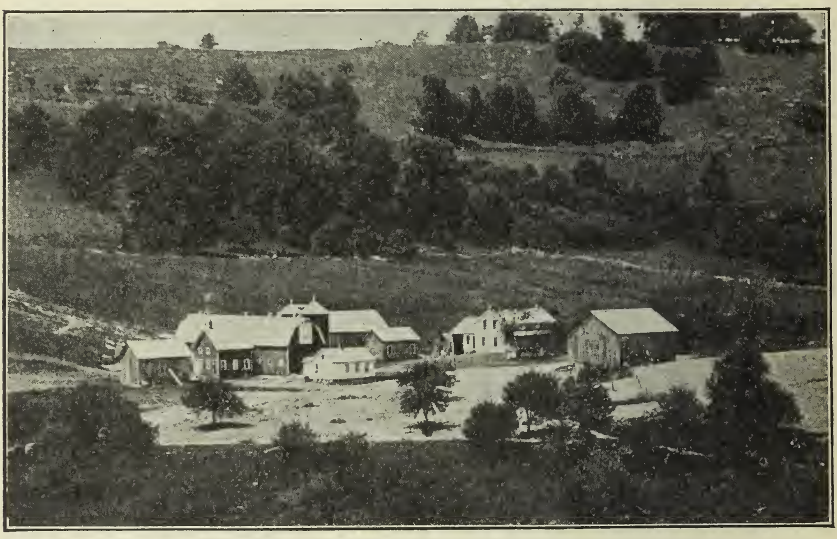

FIG. 2.—Typical topography of the Eastern dairy farm, where the dairy is the dominant factor in determining labor requirements.

Thus it will be seen that there are two distinct types of dairy farming in vogue in this country—the strictly dairy type of the comparatively rugged Northeastern States and the mixed type which prevails throughout the dairy regions of the Middle West.

In order to determine the effect of the milking machine upon the organization and economic management of the dairy farm in general, it was necessary to secure data from farms of both these types as well as from farms representative of both the hand and the mechanical method of milking. Further, it was necessary not only to select areas which exemplified dairying under different conditions, but also those in which a comparatively large number of mechanical milkers was in operation. The data were obtained from 109 New York dairy farms as representative of the intensive type and from 160 farms in the Central States as representative of the mixed type of farming. These studies were made by interviewing the dairyman in every case and learning his experience with milking machines. The studies covered a period of several months during the summer and autumn of 1915, and the data secured are representative of conditions existing on these farms during the entire year. The dairymen interviewed had used the milking machine for periods varying from one to six years.

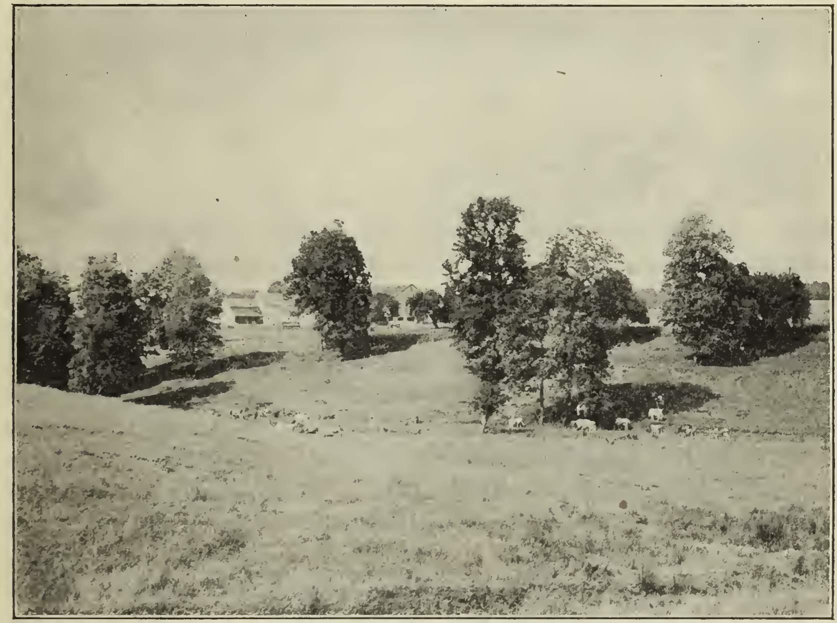

FIG. 3.—Typical topography of the dairy farm of the Middle West, where conditions are more favorable to crop production than on the Eastern dairy farm.

AREAS STUDIED.

The areas chosen for this study are located in Delaware, Chenango, and Chautauqua Counties, N. Y.; Lenawee County, Mich.; Fulton County, Ohio; and McHenry County, Ill. Dairying in a very intensive form is practiced in the New York areas. In the Ohio and

Michigan localities dairying is combined with general farming. In McHenry County, Ill., the dairy is a more important part of the farm business than in the Ohio–Michigan area, but it does not assume as large a proportion of the total farm business as on the farms studied in the New York counties. All of these localities are adjacent to large cities, and the bulk of the milk produced is sold to local creameries, which, in turn, ship much of it in the form of whole milk to the cities. In each of these localities a considerable number of the various kinds of mechanical milkers was found.

LABOR REQUIREMENTS OF DAIRY FARMS.

Dairying is a type of farming which is very dependent upon labor. The degree of dependence is governed by the intensity of the dairy industry on the farm. The strictly dairy farm, the one receiving nearly its entire income from dairy stock and dairy products, if operated at full capacity, usually carries as large a dairy herd as the farm is capable of supporting.

Such a dairy farm, as commonly organized in the North Atlantic States, often receives from 90 to 95 per cent of its total income from dairy products and dairy stock. It is divided into fields and pastures which are so proportioned as to enable the farm to support a nearly uniform number of dairy animals throughout the year. Under such a farming system the labor necessary to grow and harvest the crops is not adequate to care for a herd large enough to consume them. The number of milking cows kept is one of the important factors which determine the labor required on the farm. This is due to the fact that on the type of dairy farm referred to here the labor required to milk is greater than that required for the other farm operations. Milking is conditioned both by time and physical limitations. It must be done at regular intervals and requires enough milkers to complete it within certain time limits. It is not ordinarily possible for one man to milk as many cattle as he can raise and harvest crops for and otherwise take care of. Under an intensive system of dairy farming it normally requires three men to milk by hand a herd which two men are capable of caring for otherwise. Unless there is some other enterprise which will profitably employ the extra man's time between milking intervals, there is a loss of efficiency of the labor on the farm. It is in the adjustment of this labor problem that the milking machine enters as an important factor, as a man can milk more cows in a stated time by machine than by hand. Two men operating mechanical milking units can do the work of three men milking by hand. In Cornell Bulletin No. 364, "Cost of Producing Milk on 174 Farms in Delaware County, N. Y.," the author states: "After feed, labor was the most important cost factor in the production of milk. Excluding the hauling of milk, the labor cost represented 18.9 per cent of the total cost."

TABLE I.—*Relation between man labor employed, crops grown, and stock kept on farms in the areas studied.*

FARMS WITHOUT MILKING MACHINES.

Area.	Number of farms.	Average size (acres).	Number of men employed per farm per year.	Acres of crops raised per farm.	Acres of crops per man.	Number of dairy cows per farm.	Number of dairy cows per man.
New York	53	191.4	2.16	73.8	34.2	30.8	14.3
Michigan-Ohio and Illinois	60	146.7	2.14	90.75	42.4	20.5	9.6
FARMS WITH MILKING MACHINES.							
New York	56	213.9	2.12	71.4	33.7	34.9	16.5
Michigan-Ohio and Illinois	100	166.4	2.22	98.3	44.3	23.7	10.7

As is shown in Table I, the farms studied in the Michigan-Ohio and Illinois areas have a larger proportion of their total acreage in crops than those studied in New York. They raise more crops per man employed and keep fewer dairy cows. From the standpoint of the labor they employ, their organization is much better than that of the New York dairy farm, in that there is much more uniformity between the help required to care for the herd and that needed to care for the farm crops. Even upon farms of this type, however. the milking machine has become important, owing to the scarcity of dependable farm labor and of good hand milkers.

The use of the mechanical milker did not affect the number of acres of crops cared for by one man on the farms studied in either the New York or the Central States areas, but in both of these localities a man was able to care for and milk more cows on those farms having milking machines. On the New York farms having mechanical milkers 16.5 cows were kept per man, as against 14.3 cows per man on those farms which depended upon hand milking. The farms in the Michigan-Ohio and Illinois areas having milking machines kept approximately one cow more per man employed than those without machines. The milking machine made it possible to increase the size of the dairy without increasing the amount of labor needed to care for it.

SIZE OF HERD AND LABOR REQUIREMENTS.

Table II shows that large dairy farms require proportionately less labor to operate them than do farms keeping small herds. The same fact is brought out in a different way in Table III, where it is shown that it requires more time to care for a cow in a small herd than one in a large herd.

TABLE II.—*Relation between man labor employed, size of dairy herds, and use of mechanical milkers.*

Area and size of herd.	Number of herds of each size.		Number of men employed per farm.		Number of dairy cows per farm.		Number of dairy cows per man.	
	On farms with machines.	On farms without machines.	On farms with machines.	On farms without machines.	On farms with machines.	On farms without machines.	On farms with machines.	On farms without machines.
Michigan-Ohio and Illinois area:								
15 cows or less	26	20	1.68	1.47	12.3	11.35	7.3	7.7
16 to 30 cows	54	34	2.19	2.33	22.9	22.8	10.4	9.8
31 to 50 cows	16	6	2.51	3.29	36.4	38.3	14.5	11.6
51 or more cows	[1] 3	....	3.73	....	55.0	....	14.7	....
New York area:								
15 cows or less	6	8	1.0	1.51	10.3	12.9	9.95	8.5
16 to 30 cows	18	29	1.59	1.91	21.4	23.1	13.5	12.1
31 to 50 cows	25	10	2.38	2.5	40.6	42.0	17.1	16.8
51 or more cows	[2] 6	[3] 5	2.66	3.82	68.2	72.0	21.9	18.8

[1] One farm in this group peddled milk in town and required extra labor; therefore it was not used in this table.

[2] One farm in this group made butter, which raised the labor requirement of the farm. The report was not used in this table.

[3] On a farm in this group only a small proportion of the cows kept were milked. The report was excluded from this table.

Table II also shows, under the heading "Number of men employed," that for herds of the same size slightly less labor is employed on farms where the milking machine is used. This is true in both New York and the Central States. In both sections those farms using milking machines kept about two more cows per man. The column headed "Number of dairy cows per man" refers to the number of cows kept for each man employed on the farm throughout the year. It is shown that the farms having larger herds keep more cows in proportion to the labor employed.

The amount of labor required to care for the herd and the period of the year when the labor demands are greatest are important factors in determining the labor available for other farm work. In the areas which were covered by this study it is the common practice to maintain the herds on pasture during the growing season, which may be roughly defined as between May 15 and November 1. During this period the cows demand little attention other than that required in getting them up to milk and turning them back to the pasture again, both night and morning. On most farms they are given supplementary feeds during the late summer, but this is usually in the form of grain which can be fed in a few minutes when the herd is in the stable. Occasionally some roughage is fed also. This consists mostly of green corn cut and fed in the pasture lot or stable, which operation takes considerable extra time. The time taken to feed in the summer, however, is offset by the fact that in those herds where feeding is practiced the cattle come for their feed at milking time, while in the case of the herd not fed it is necessary to go after them.

From November 1 to May 15 the cattle are stabled, and during the period they require considerable attention. In addition to feeding the stock the stables and the cattle themselves have to be kept in a clean and sanitary condition.

Table III shows the time spent during the summer and winter seasons in the care of the herd. The table also show that there is proportionately much more labor required per cow to care for the small herds. In the New York area, on farms where hand milking is practiced, the total time spent annually to care for and milk the dairy herd was 173.7 hours per cow in the herds of 15 cows and less, as compared with 118.2 hours per cow in the herds of 51 or more cows.[1]

TABLE III.—*Hours of man labor per year required to care for and milk a cow in herds of different sizes, and when milked by hand or by a mechanical milker (hauling to market not included).*

Area and size of herd.	Number of herds of each size.		Hours of man labor per cow per year.							
			Care of cow (milking excluded).				Milking.		Total hours per year.	
			Total for pasture season.[1]		Total for remainder of year.[2]					
	On farms having machines.	On farms not having machines.	On farms having machines.	On farms not having machines.	On farms having machines.	On farms not having machines.	On farms having machines.	On farms not having machines.	On farms having machines.	On farms not having machines.
Michigan-Ohio and Illinois areas:			*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*
15 cows or less	26	20	18.6	16.9	73.75	65.6	57.2	92.95	149.55	175.45
16 to 30 cows	54	34	11.6	17.7	53.2	56.8	53.8	84.5	118.6	159.0
31 to 50 cows	16	6	7.8	5.7	46.0	49.6	53.5	85.2	107.3	140.5
51 or more cows	4	......	15.4	......	36.6	......	38.0	......	90.0	......
New York area:										
15 cows or less	6	8	16.0	16.0	96.8	77.7	65.5	80.0	178.3	173.7
16 to 30 cows	18	29	7.3	12.6	46.1	52.9	56.1	82.0	109.5	147.5
31 to 50 cows	25	10	7.0	7.1	40.7	52.4	47.3	82.4	95.0	141.9
51 or more cows	7	6	5.7	5.6	33.5	26.3	39.7	86.3	78.9	118.2

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[1] Cornell Bulletin No. 364 shows that in Delaware County, N. Y., 20 per cent of all the labor spent in the care of the herd is furnished by the women and children of the family. Proportionately more family labor is furnished on the smaller farms. The larger dairy farms are very dependent upon hired labor and it is often found difficult to secure sufficient help.

Men who are hired by periods of a month or longer are commonly employed in the care of the dairy and to milk. The average wages paid to this class of labor were very uniform in all the areas included in the study, and were as follows: In New York, $28 per month; in Illinois, $29.50 per month; and in the Michigan-Ohio area, $28.85 per month. The unmarried farm worker was furnished with his board, and the married man with a house, wood, milk, etc. Other investigations carried on by the Office of Farm Management show that the value of a farm worker's board is approximately $12 per month. The value of a tenant house, wood, milk, etc., furnished to the married farm hand is considered about equal to the value of board.

The total average value of wages and board is therefore $40.75 for all the areas.

There are 26 working days per month. It is estimated that the dairyman works 12 hours each working day. He also works 4½ hours on Sunday. This makes a total of 330 hours per month. The cost per hour of labor figured on this basis is 0.123 cent.

[2] The exact dates of stabling cattle in the fall and turning them out to pasture in the spring vary with the season and the practice of the individual dairyman. Cattle are commonly stabled from approximately November 1 until May 15, a period of 200 days. The balance of the year (165 days) they are on pasture.

The use of the mechanical milker has little, if any, bearing on the time required to care for the dairy herd other than that of milking. When the total time required to care for and milk a cow is considered, it will be noted that, with the exception of the herds of 15 cows or less in the New York area, in all cases a cow on those farms on which mechanical milkers are used requires fewer hours of labor per year. This is due to the saving in the time required to milk through the use of the milking machine.

When a cow is milked by hand more time is required for milking than for the care and feeding of the cow. As the size of the herd is increased this difference becomes greater. On the larger dairy farms using mechanical milkers the time required to milk a cow nearly equals the time required to feed and care for her. This is very similar on the New York farms studied, while on the farms studied in the Ohio, Michigan, and Illinois areas it requires somewhat less time to milk a cow than to care for and feed her.

THE MILKING MACHINE.

The milking machine had received considerable attention in Australia and New Zealand prior to its introduction in this country. In 1849 the first United States patent for a mechanical milker was issued, but the development of the milker did not reach the stage where its efficiency made it an economic factor until within recent years.

The labor problem of the dairy farm has for a long time been a troublesome one, made so by the large amount of help required to milk as compared to that needed for the other farm work. This condition, as well as the fact that excessive hand milking is not only distasteful to many dairymen but also often injurious to hands and wrists, has created a demand for an efficient and economical mechanical milker. Various State experiment stations have published bulletins treating on the efficiency of certain types of milking machine, but very little information has been made available which will show the relative cost of milking with these outfits as compared to hand milking.

The factors which determine the cost of hand milking are the time required and the cost of labor. The factors which determine the cost of milking with the mechanical milker are: Time required to operate, wages paid to operators, interest on investment in outfit, repairs, cost of power, and depreciation.

THE TIME FACTOR.

Table IV shows that on the farms keeping 15 cows or less it takes 7.3 minutes to milk a cow by hand and 4.8 minutes to milk a cow with a mechanical milker. On the farms keeping larger herds it takes proportionately less time to milk with mechanical milkers, but where hand milking is practiced the time required to milk a cow does not vary appreciably with the size of the herd. These facts indicate that the mechanical milker may be used with more efficiency in the larger herds than in the smaller ones. The time required to milk, both by hand and by machine, was figured on the basis of the average time per milking year for each cow in each herd. In the case of machine milking this includes the time necessary to clean and care for the machine. The normal lactation period of a cow is from 9 to 11 months. Therefore the actual time required to milk per milking may be slightly higher, varying with the length of the lactation period.

TABLE IV.—*Time required per milking, by machine and by hand, for herds of different sizes in areas studied.*

Size of herd.	Hand milking.				Machine milking.			
	Number of farms.	Number of milkers per herd.	Minutes per milking per cow.	Number of cows per milker.	Number of farms.	Number of operators per herd.	Minutes per milking per cow.	Number of cows per operator.
15 cows and less	28	1.4	7.3	8.25	32	1.1	4.8	10.6
16 to 30 cows	63	2.4	6.85	9.7	72	1.5	4.45	15.3
31 to 50 cows	16	3.1	6.85	13.3	41	1.9	4.1	20.5
51 cows or more	6	4.3	7.1	17.0	11	2.4	3.2	27.8
Average	113	2.3	6.95	10.8	156	1.6	4.15	17.6

Should most of the milk from the herd be produced during the spring and summer season when the other farm work requires a maximum of attention, the time saved by the use of the milking machine may be devoted to the raising and harvesting of farm crops, thus eliminating the need for the extra day labor which is often hired for this purpose.

A comparison of the columns "Number of cows per milker" under the heading "Hand milking" and "Number of cows per operator" under the heading "Milking machine" shows that a man using a mechanical milker is capable of milking more cows than he can milk by hand. This advantage becomes important with the increase in the size of the herd.

Table V shows that on farms where milking machines are used the average farmer estimates that the use of the machine enables him to operate his farm with a saving in wages paid to hired labor. This saving is partly due to the elimination of day labor.

THE COST FACTORS.

As the use of the milking machine makes it possible for a man to milk a greater number of cows, and as very often milking is the factor determining the labor requirement, the installation of the milking machine replaces some of the regularly employed help. The value of the labor replaced yearly by the mechanical milker varies, according to estimates made by the dairymen interviewed, from $2.63 per cow in herds of 15 cows or less to $8.33 per cow in herds of more than 50 cows. There is an addition to the time available for field work, varying from 1.5 hours of man labor per day on farms keeping herds of 15 cows or less to 5.1 hours on farms keeping herds of over 50 cows, due to the use of the milking machine. To this may be attributed, in part, the reduction in labor hired. As previously mentioned an increase in the time available for field work makes it possible to do more work with the regular force and often eliminates the necessity of hiring extra help.

TABLE V.—*Saving due to machines in time and in wages paid to hired labor as estimated by the dairymen interviewed.*

Size of herd.	Number of farms with herds of each size.	Farmers' estimate of hours of working [1] time saved by use of the mechanical milker (per day, per farm).	Estimated saving of wages paid to labor due to the use of the milking machine (per cow, per year).
15 cows or less	32	1.5	$2.63
16 to 30 cows	72	2.2	5.93
31 to 50 cows	41	3.0	4.93
51 cows or more	11	5.1	8.33

[1] Such time as is saved from milking is available for a man and team. When the laborer leaves his work to milk, if he is using a team it must be stabled; hence, man and horse time is affected, depending upon the nature of the work.

TABLE VI.—*Comparative annual costs of hand and machine milking on farms with herds of different sizes in the areas studied.*

Size of herd.	Machine milking.							Hand milking.	
	Number of farms with herds of each size.	Interest on investment (per cow).	Value of gas and oil (per cow).	Cost of repairs (per cow).	Depreciation (per cow).	Labor cost (per cow).	Total cost (per cow).	Number of farms with herds of each size.	Labor cost (per cow).
15 cows and less	32	$1.26	$0.94	$0.20	$1.98	$7.39	$11.77	28	$10.91
16 to 30 cows	72	.79	.84	.20	1.00	7.31	10.14	63	10.26
31 to 50 cows	41	.61	.84	.25	1.49	6.03	9.22	16	10.11
51 cows or more	11	.56	.83	.36	1.12	4.47	7.34	6	10.45
Average	156	.82	.86	.22	1.24	6.79	9.93	113	10.41

The labor cost of milking by hand and by machine milking is shown in Table VI. Wages are figured at 0.123 cents per hour. The labor costs conform to the time required to milk by hand and machine milking as shown in Table IV. They remain nearly the same in herds of various sizes when hand milked, but diminish in the larger herds when the milking machine is used. Each of these items will be considered in detail.

INTEREST ON INVESTMENT.

Interest on investment is a widely variable item. When the type of milker used is the same, the investment charge per cow is much smaller in the large than the small dairies. This is because a power plant, piping, etc., have to be installed in the small as well as in the large dairy, and the difference in the costs of these equipments is not proportional to the number of cows they serve. There is considerable variation in the costs of the different kinds of mechanical milking outfits on the market. The comparatively expensive outfits are more frequently used on the farms having larger dairies; therefore, the investment per cow is not as much smaller in these large herds as it would appear that it should be.

COST OF POWER.

The cost of power per cow falls slightly as the number of cows milked increases. The time consumed per cow is greater in a small herd than in a large one.

Power for the operation of milking machines is usually furnished by means of a gasoline engine. It does not ordinarily pay to use an engine which develops much excess power, as it requires too much gasoline. Where it is necessary to pump water this is often done at milking time, and a larger engine may be profitably used to do the extra work. The cost of power furnished by a gasoline engine depends on the local prices of gasoline and oil, and the efficiency with which the engine is operated. Electric motors are sometimes used as a source of power on farms near large towns where current from a power line is available. This form of power is sometimes more expensive, but perhaps is more reliable than gasoline. In special cases, as, for example, where the herd is large and extra labor for emergency hand milking not available, it may sometimes be worth the extra investment incurred to have a second gas engine large enough to operate the milker, set up in such a manner that in case of accident to the engine regularly used it could be pressed into service without loss of time.

REPAIRS.

The repair costs seem to be greater per cow for the larger herds. This is probably due to the fact that with such herds more cows are milked with a milking unit than with the smaller herds. The repair costs are largely confined to the rubber tubing and rubber linings of the teat cups.

DEPRECIATION.

It is not possible, in view of the short time the mechanical milker has been in general use, to secure accurate data on the rate of depreciation of such machines. Some of the parts, such as the vacuum tank and the iron piping, should last almost indefinitely. The pails, if heavily nickeled or made of nickel alloy or other noncorrosive metal, should last for a number of years. The parts most subject to depreciation, the rubber tubes and teat cup rubbers, are normally subject to such frequent renewal that the cost of keeping them up has been included under repair costs. The parts always subject to a certain amount of wear are the engine, pump, and pulsator. Reliable data is at hand to justify the assumption that the depreciation of the small stationary engine averages not more than 10 per cent per year. Since the pump is much less complicated than the engine and is not subject, as is the engine, to deterioration due to excessive heat, it may be assumed that the life of the pump is somewhat longer than that of the engine. This leaves the pulsator, the cost of which is not more than 25 per cent of the total cost of installation, as the only wholly unknown quantity. All things considered, it has been thought safe to assume that the life of the outfit as a whole, not counting rubber parts, is slightly longer than the known life of the engine. Hence 8 per cent per year has been taken as the rate of depreciation of milking-machine outfits in this discussion. It should be borne in mind, however, that this figure is a somewhat arbitrary one, used in this connection only for lack of any more definite figure and that it applies to the entire outfit, exclusive of rubber parts. It was felt that the use of even this rough approximation would tend to make the results of this study more reliable than they would have been had depreciation been ignored altogether.

The depreciation charge, like the investment charge, is affected by the initial cost of the milking outfit. When an arbitrary depreciation figure is applied to all outfits the more expensive ones receive a higher depreciation charge. In actual use, however, the depreciation is determined by the initial cost and the length of life of the machine, with the last factor the more important.

COMPARATIVE COST OF MILKING BY HAND AND BY MACHINE.

As previously stated, the cost of hand milking is determined by the time taken to milk and the wages paid to the milkers. In figuring the cost of milking with the mechanical milker the following items were considered in addition to the labor cost: The interest on the investment, the fuel expense or cost of power, and the repairs and depreciation. The actual cost of milking a cow by the two methods is shown by Table VI. The tables indicate that a cow in a herd of 30 cows or more can be milked more profitably by the mechanical milker than by hand. In the dairies of 15 cows or less the actual cost of hand milking is less than by machine milking. Table V, however, shows that the use of the machine eliminates the hiring of some help on these farms, as it permits the operator to milk alone a number of cows which he would require additional labor to milk by hand. Such a condition is found on farms where the operator has become physically unfit to milk, because of the weakening of muscles in his hands and wrists. Some farmers do not like to milk and prefer either to hire labor for this purpose or keep small dairies. The milking machine also assures the farmer of being able to do the milking in case of sickness among his working hands or if any of them should leave. In this way it makes the dairyman less dependent upon hired help.

EFFECT ON COWS.

Tests conducted by various State experimental stations show that practically the same milk yields were secured from cows whether they were machine milked or hand milked.[1] The bulletins reporting these experiments, however, emphasize the fact that when the mechanical milker is successfully operated it must be in the hands of a competent man, and that stripping after the machine is absolutely essential if satisfactory results are to be obtained. Information obtained in this study substantiates these statements.

A reasonable amount of care and intelligence must be exercised by the operator if good results are to be expected. It is not a good plan for the operator to attach a milking unit to a cow and go away while it is in operation. When the milker has drawn all the milk that will be given freely by the cow it is a saving of time to remove it and place it on the next cow to be milked. Strippings can be drawn much more quickly by hand and with less chance of injury to the cow. Many users of milking machines are of the opinion that best results are obtained from them if certain of the milking force are assigned to operate and others strip after the machine. Stripping the cows after the machine is removed not only saves time but also affords opportunity for examining the udder.

In order to ascertain the effect, if any, of the mechanical milkers on the milking qualities of cows in the dairies where they were used, two questions were asked the dairyman operating them. Following are these questions, with summaries of the answers received.

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[1] Kentucky Exp. Sta. Bul. No. 186; New York Exp. Sta. Bul. No. 317 (Geneva); Wisconsin Exp. Sta. Bul. No. 173.

(1) Has the use of the mechanical milker influenced the production of your herd?

There were 156 answer as follows:

No difference.	Less.	More, if anything.
124	16	16

(2) Do you find that the machine has magnified or lessened sore teats, spider in the teats, garget, milk fever, and other udder troubles?

There were 129 answers as follows:

No difference.	Less trouble from udder diseases.	More trouble from udder diseases.
110	11	8

Thus it appears that the majority of the farmers visited believe that the milking machine has no effect one way or another in the general welfare of the herd. These figures are given merely as indicative of the trend of opinion among farmers; they are not to be taken as conclusive. A conclusive answer to these questions could be given only after a careful and comprehensive study.

EFFECT OF AGE OF COW ON EFFICIENCY OF MACHINE MILKING.

The readiness with which a herd of cows becomes accustomed to the milking machine depends upon several factors, the most important of which is the age of the animals. It is the general experience of farmers that young cows which are broken in to milk with the mechanical milker take to it more readily than older ones which have become accustomed to hand milking. They become used to it in a shorter time and milk out cleaner than older cows. Many young cows are difficult to milk by hand on account of their short teats. Short-teated cows and "hard milkers" are as easily milked by the machine as any others.

A herd which has been roughly treated becomes nervous and will not be broken in to the milking machine as readily as one which has been handled more gently. Some old cows never will become accustomed to the milking machine so as to be milked satisfactorily by it. It is best to milk such cows by hand or to sell them. On the other hand, cows averse to hand milking have been milked with good results by the mechanical milker.

STAGE OF LACTATION PERIOD.

When a cow's lactation period has so far advanced that she becomes a "stripper" many farmers think that it is a waste of time to put the milker on her. Hence it is a common practice to discontinue using the milking machine on cows that are nearly dry and strip by hand. In herds where most of the cows become nearly dry at one time the use of the mechanical milker is often discontinued altogether for a time until cows enough come in to enable the machine to be operated economically.

TABLE VII.—*Comparative efficiency of various combinations of milking units and operators in the operations of mechanical milkers.*

Number of operators [1] and milking units.	One-cow milker.		Two-cow milker.	
	Number of farms.	Minutes per cow per milking.	Number of farms.	Minutes per cow per milking.
1 operator, 1 milker	....	....	14	4.75
1 operator, 2 milkers	28	4	19	3.35
1 operator, 3 milkers	7	3.65	....	....
2 operators, 2 milkers	10	5.25	24	4.45
2 operators, 3 milkers	21	5.2	....	....
2 operators, 4 milkers	11	4.85	....	....
3 operators, 3 milkers	4	5.3	....	....

[1] The term "Number of operators" as used in the above table means the number of men who either operate the machine or strip.

EFFICIENCY OF MILKING COMBINATIONS.

Of the different kinds of milking machines in common use about half milk one cow at a time and the other half two cows at a time. They are called, respectively, one and two unit outfits. Each has certain advantages.

Table VII was made by averaging the time taken to milk a cow by the several combinations of milking units and operators most commonly used. This table indicates that the greatest speed in milking is made when one man operates and strips after two double milking units. On farms where one man operates and strips after three units the cows must be stripped hurriedly. Too rapid stripping is not desirable when it is done at the expense of the thoroughness of the work.

There are various conditions, however, which will determine what is the best combination to use in milking. The ability of the operators to change the machines and attend to the cows, the readiness with which the cows let down their milk, and the time required to strip, all enter into the determination of the best milking combination.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 424

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

UNIVERSITY
DEC 1

Washington, D. C. PROFESSIONAL PAPER November 9, 1916

THE COTTONWOOD BORER.[1]

By F. B. MILLIKEN, *Scientific Assistant, Truck-Crop and Stored-Product Insect Investigations.*

INTRODUCTION.

When the writer was stationed at Garden City, Kans., in 1913, some of the first inquiries he received were for methods of preventing injury by borers to shade trees—cottonwood (*Populus deltoides*) and willow (*Salix alba*). Neither entomological literature nor inquiries made of other entomologists regarding the cottonwood borer yielded accurate information upon which remedial measures might be based. Investigations were begun, therefore, to determine the life history and habits of the insect. Its large size and the obvious character of the injury it accomplishes have facilitated the securing of results, which are here given.

DESCRIPTION.

THE ADULT.

The cottonwood borer (*Plectrodera scalator* Fab.) is one of the largest beetles found in Kansas, the male measuring from 1.25 (3.2 centimeters) to 1.375 inches in length by 0.40 inch (1.1 centimeters) in greatest width, and the female about 1.5 inches long (3.5 centimeters) by 0.50 inch (1.2 centimeters) in width. The ground color in both sexes is shining black overlaid by stripes and patches of cream-colored scales. On each elytron the black shows through in two rows of irregularly rectangular patches, and there is a black patch on each side and one on the top of the prothorax. The antennæ are black, except the first two segments, which, with the legs, appear rusty or grayish from a scattering covering of the light scales. Much of the ventral surface is also covered with light scales, although not so thickly as the dorsal. In both sexes the prothorax

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[1] The investigations of the cottonwood borer (*Plectrodera scalator*) were begun prior to the reassignment of shade-tree insect problems to the Branch of Forest Insect Investigation.—F. H. CHITTENDEN.

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bears a strong, sharp spine on each side. In the female the antennæ reach the apex of the abdomen, while in the male they reach a fourth of an inch or more beyond, and the segments are thicker and longer. The male beetle is illustrated by Plate I.

THE EGG.

The egg is 0.12 to 0.15 inch (from 3 to 4 millimeters) long by about 0.10 inch (2.5 millimeters) thick and is elliptical in shape. The outer covering is pliable, but very tough, being almost leathery. It is yellowish or light brown in color.

THE LARVA.

The newly hatched larva is of the usual cerambycid form. In color it is white with black mouth parts and is much wrinkled transversely. It is about 0.20 in. (5 millimeters) long by 0.07 inch (2 millimeters) across the widest part, which is just behind the head. Little change occurs in color during the larval stages, but the length may increase eleven times and the width five or six times, making the mature larva nearly twice as long in proportion to its width as the newly hatched larva. (Fig. 1.)

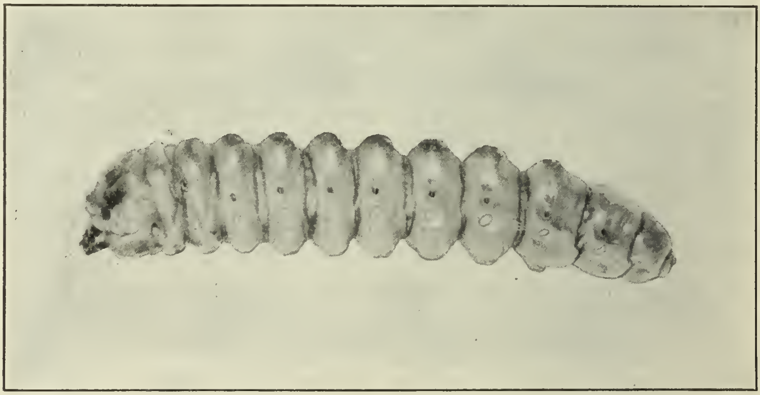


FIG. 1.—The cottonwood borer (*Plectrodera scalator*): Larva, lateral view. Enlarged. (Original.)

THE PUPA.

Of five pupæ the average length was 1.40 inches (3.5 centimeters) and the average width 0.80 inch (2 centimeters). When first formed the pupa is dull white, but the points soon become dark. The femur and tibia of each leg are folded against each other and placed transversely on the ventral surface of the body, with the tarsi extending backward beside the median line. The wingpads are folded obliquely downward and backward, passing between the body and the first two pairs of legs, the tips extending under the posterior pair of legs. The antennæ curl outward and backward dorsally to the two anterior pairs of legs, then ventrally and inward nearly to the median line and forward along the tarsi, where they end with the apices or tips pointing nearly outward just below the legs. (Fig. 2.)

LIFE HISTORY AND HABITS.

OVIPOSITION.

The female deposits her eggs in the trunks of cottonwoods and willows at, or a little below, the surface of the ground. A preliminary examination is made, which, among very small trees, may include the bases of several. When satisfied with her selection, the female clings securely to the bark with her head toward the ground, and by means of her strong jaws loosens the surface soil. This she pushes away with her head by straightening her front legs and thrusting her body outward from the tree. In this manner the soil may be removed to the depth of half an inch. A hole is then made in the bark to receive an egg. In small trees, especially in cuttings set during the preceding spring, this hole may extend through the bark well into the wood. In any case the bark and wood are torn to shreds by the strong jaws of the insect, and some of these shreds usually remain attached to the small round cavity intended for the egg.

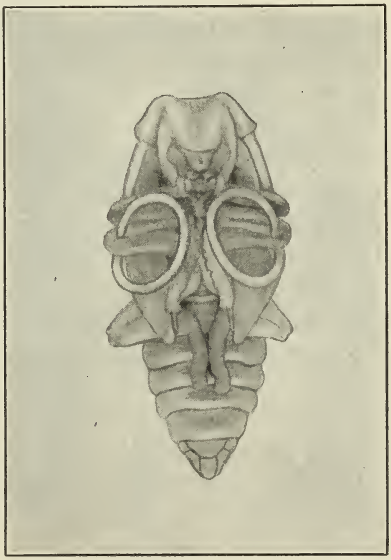


Fig. 2.—The cottonwood borer: Pupa, ventral view. Enlarged. (Original.)

After completing the egg cavity the female turns round and backs into the excavation, locating the cavity with the tip of her abdomen. She then secures a firm hold on the bark and remains in this position for several minutes, during which time much muscular activity is evident at the tip of the abdomen. The egg is finally extruded and pushed firmly into the cavity intended for it. A quantity of a dark gelatinous substance is deposited around and over the egg, and the adhering wood fibers are patted into place with the tip of the abdomen. The wound is then covered and the depression usually filled with earth by means of the abdomen, which is carried outward from the tree and drawn back against it with the tip scraping the loose soil. All evidence of injury to the tree is often obliterated by the first succeeding shower. In the instances under observation oviposition required about one hour.

After the egg has been covered the female crawls aimlessly about the tree trunk. Her wanderings usually end among the branches, where copulation may occur, some of the tender leaves may be eaten, or the female may take wing from the tip of a branch.

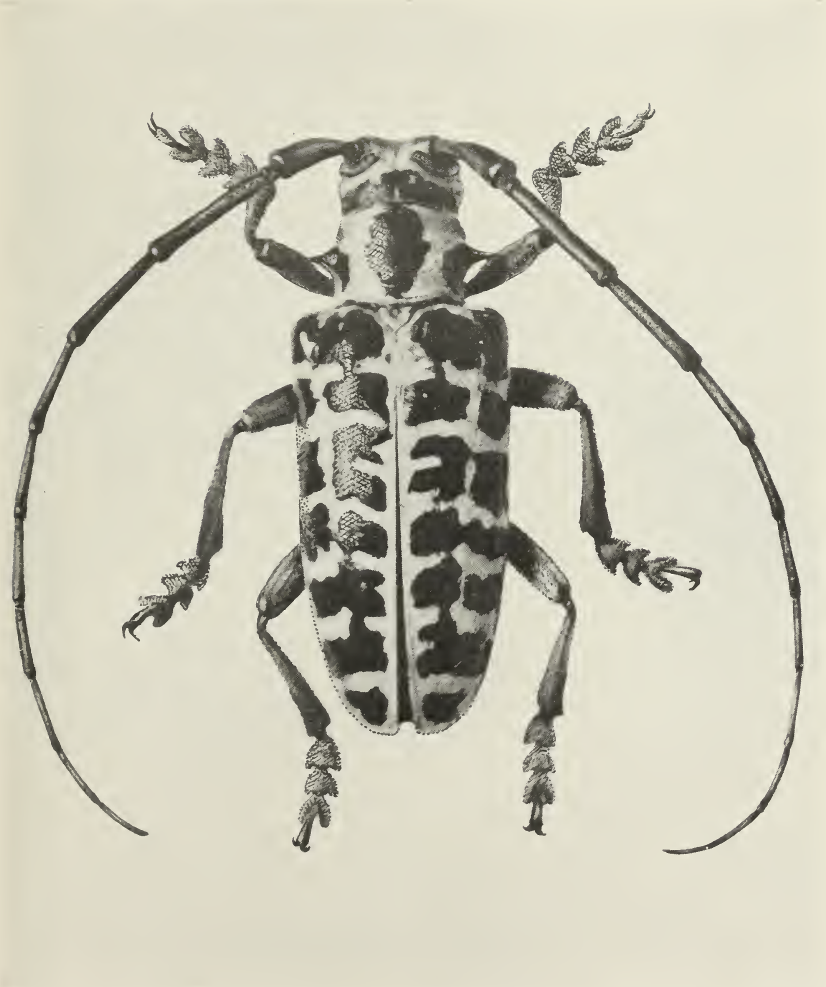
The place of oviposition was discovered in July, 1913, when the wind blew down cottonwood and willow cuttings in the Forest Service nursery at Garden City, Kans. The forest supervisor, Mr. B. R. H. D'Allemand, brought in damaged cuttings to learn the cause of the injury at the surface of the ground. Field observations revealed eggs in the wounds on the sides of the cuttings, and these eggs were identified as those of the cottonwood borer. Later they were discovered in trees of all ages, and adults were observed in the act of oviposition. The cuttings and younger trees were preferred for egg laying.

In 1913 the injury to cuttings was reported on July 29. At that time the edges of many of the wounds had healed and many of the eggs had hatched and the young had worked well into the tree. About two weeks are required for hatching; the eggs, therefore, must have been deposited about July 10. On July 9, 1914, eggs were found that had been deposited after July 4, as the work was fresh and the last preceding rain occurred on the latter date. Oviposition probably extends into September, as adults were numerous on August 22, 1914, and one was found on August 28, 1913. Mr. C. H. Popenoe collected both sexes at Dodge City, Kans., September 23, 1913. They were abundant, and several were found in copula.

One female after depositing 2 eggs was found on dissection to contain 13 others of different sizes, a total of 15; another female deposited 1 egg and contained 15, a total of 16; a third deposited 1 egg and contained 16, a total of 17; and a fourth contained 23 after depositing 1, a total of 24. During July of 1914 the average period of incubation for 14 eggs was 13 days.

DEVELOPMENT OF LARVA.

On hatching, the young larva works out of the egg cavity and begins to bore in the tender bark just outside of the wood. The tunnel which it forms is usually filled behind it with excrement and fine pieces of wood. As cold weather approaches it passes into the wood, remaining either above or below the ground level. During



THE COTTONWOOD BORER (PLECTRODERA SCALATOR): MALE BEETLE. MORE THAN TWICE NATURAL SIZE. (ORIGINAL.)

November, 1913, and January and February, 1914, the larvæ that hatched in 1913 varied in length from 0.70 inch (1.75 cm.) to 1.0 inch (2.5 cm.). By September, 1914, they had grown to 1.20 inches (3.25 cm.) and 2.0 inches (5 cm.). By the spring of 1915 nearly all were more than 1.60 inches (4 cm.) long, some reaching 2.20 inches (5.5 cm.).

During the second winter the larvæ occupy large tunnels that reach from the inside of the bark near the ground level to the bark several inches below. Both ends of the tunnel are plugged with excelsiorlike fibers of wood, the larva resting on the lower plug. In the spring, before transforming to the pupa, the larva cuts through the bark at the upper end of the tunnel, and plugs the openings with wood fibers.

TIME AND PLACE OF PUPATION.

In 1914 pupæ were secured on June 23. Of the larvæ reared from the 1913 material, one was found as a pupa when examined on July 3, 1915. Another was found as a dead pupa a few days later.

The pupa rests back downward on the fiber plug at the lower end of the tunnel which was occupied by the larva during the second winter.

EMERGENCE OF ADULT.

One adult, which was reared from a larva hatched in 1913, emerged on July 13, 1915. In 1914 adults emerged from 12 screened trees from July 8 to August 4. However, as noted, eggs were secured that had been deposited about July 4, which indicates that emergence occurred during the last of June, and one report was received on June 16 that adults had been seen several days before. The period of emergence thus computed is about 50 days.

NATURAL ENEMIES.

Several young larvæ were found dead, overgrown with a fungus. No instances of parasitism were observed during the investigations.

METHODS OF CONTROL.

The desirability of developing control measures will be understood from a perusal of the following figures. On September 15, 1913, the bases of 10 trees that varied in diameter from 4 to 8 inches were examined for eggs and larvæ. The number of eggs, small larvæ, and large larvæ, and of the tunnels that penetrated too deeply into the wood for their extent to be ascertained, are shown in Table I.

TABLE I.—*Record of damage by the cottonwood borer (Plectrodera scalator) to 10 trees at Garden City, Kans., 1913.*

	Tree No.—										Total.
	1	2	3	4	5	6	7	8	9	10	
Eggs	2	0	0	0	0	0	0	0	0	0	2
Small larvæ	9	5	4	6	10	7	14	8	6	9	78
Large larvæ	0	1	2	1	0	0	0	0	0	0	4
Tunnels	2	2	1	2	0	0	2	8	2	1	20

The total of the eggs and small larvæ was 80, an average of 8 to a tree. Such a number of young larvæ, nearly all of which were working in the bark, would seriously check the growth of the tree, as well as render the tree liable to damage by heavy winds.

PREVENTIVE.

Since the eggs are placed only on the trunks of the trees at the surface of the ground, infestation is easily prevented by a screen cone about a foot high, wrapped about the base of the tree and with its lower edge sunk in the ground. This cone should fit the tree trunk closely at its top to exclude the beetles and be set out at the base an inch or two to prevent the eggs from being deposited through it. It can be made by cutting common window screen, usually galvanized netting, one-fourth to one-half inch mesh, into strips about 1 foot wide and of the proper length. Each strip is then slit from a third to half way across from one edge at distances of from 3 to 4 inches, as shown in the diagram (fig. 3). The screen is then wrapped around the tree, the lap fastened at its lower end with a nail, pin fashion, and

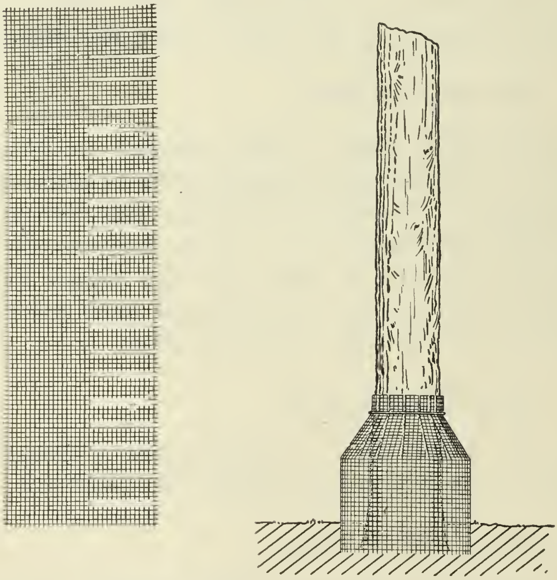


FIG. 3.—Diagram showing method of protecting trunk of cottonwood against attack by the cottonwood borer. At left, section of screen; at right, cottonwood trunk showing screen in position. Reduced. (Original.)

the lower edge sunk into the ground about an inch. The top parts of the screen should be pinned to one another with small brads so as to fit closely about the tree; or they may be held in place by a piece of binding twine wrapped around them. The same screen cone will protect a tree for several years if made large at first; but the screens should be examined during June of each year, being loosened where too tight and repaired where torn.

REMEDIES.

When the 10 trees were examined in September, 1914, all eggs and young larvæ were removed. (Table I.) Where possible the large larvæ were also removed, and the number of eggs and larvæ secured from each tree is noted in the table. The tunnels from which, owing to their depth, the larvæ could not be removed were treated with a small quantity of carbon bisulphid injected from an oil can. From the 10 trees treated in this manner only five adults emerged during 1914, whereas from two untreated trees that were screened eight adults, or an average of four beetles to a tree, emerged. However, the treatment with carbon bisulphid is of little benefit, as the larger larvæ in tunnels from which they can not be removed have done, at this stage, nearly all the injury of which they are capable. The greatest benefit arising from the careful examination of the tree trunks lies in the removal of the immature borers that are working in the bark. This work is inexpensive and is entirely practicable for shade trees.

SUMMARY.

The injury by the cottonwood borer results from the adults ovipositing in cuttings and very young trees, the young larvæ cutting the bark and preventing the sap flow, and the larger larvæ tunneling the wood, thus weakening the trees against wind.

The eggs are deposited in the younger trees principally during July and August. The larvæ work in the trees until the second summer after the eggs hatch, when the adults emerge from about the middle of June until the 1st of August.

Oviposition in shade trees may be prevented by screening the bases of the trees. The young larvæ can be removed before they injure the trees severely if the remedial work is done during the first two weeks of September, but removal of the large larvæ from deep tunnels often injures the trees more than would the larvæ if allowed to remain and complete their development.

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FARMING ON THE CUT-OVER LANDS OF MICHIGAN, WISCONSIN, AND MINNESOTA.

By J. C. McDowell, *Agriculturist*, and W. B. Walker, *Assistant Agriculturist*.

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The cut-over district of northern Michigan, Wisconsin, and Minnesota comprises an area of about 30,000,000 acres which is rapidly being developed into farms. This bulletin is based on data secured from an analysis of a year's business on 801 farms typical of this area, an investigation of farm enterprises on 80 of these farms, and a general study of farm practice in various parts of the district covering a period of several years. The purpose of these investigations was to discover the more profitable farm practices and the factors essential in the development of the region.

SUMMARY.

1. In this district net profits increase as tillable area increases. How to enlarge the tillable area economically is the first and most important agricultural problem of this region. Under present conditions the clearing of land is expensive, usually costing from $20 to $60 an acre.

2. A large acreage of unimproved land is likely to prove an unprofitable investment unless it can be utilized for wood products or pasture. If, however, its development into tillable land is possible,

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Note.—This bulletin is issued to meet the demand for a publication dealing in a popular manner with the essential problems of this region.

it offers an opportunity to expand the farm business to the full capacity of the total farm area.

3. Labor incomes average $118 on the 355 farms that have crop yields above the average, and minus $5 on the 446 farms that have crop yields below the average, a difference of $123.

4. With average yield and average price, potatoes furnish a satisfactory cash crop in practically all parts of the district. Large acreage, however, is not to be generally recommended on account of the danger of low prices resulting from local overproduction.

5. Other valuable cash crops adapted to certain areas are hay, clover seed, peas, beans, hairy vetch, potatoes, seed corn, oats, rye, wheat, barley, small fruit, and garden vegetables.

6. Early varieties of corn mature in the southern and central part, and silage corn can usually be produced over a large portion of the district.

7. Silos are increasing rapidly wherever corn can be grown. When only a few cows are kept, root crops are generally substituted for silage.

8. As there are few large cities, the demand for truck crops is somewhat limited in most parts of the district. The well-managed farms produce an abundance of home supplies, such as vegetables, small fruit, milk, butter, eggs, and meat.

9. Dairying combined with cash crops is financially profitable when production per cow is high and crop yields above the average.

10. On dairy farms of all sizes the quality of cows, as indicated by receipts per cow, is a major factor in determining labor income.

11. The production of sheep or beef cattle as a major enterprise, while not common in the district, is furnishing satisfactory incomes on a few farms.

12. Hog production may be profitably combined with dairying where corn matures and on farms where rye, barley, soy beans, or Canadian field peas can be substituted for corn.

13. On account of the opportunity to use extra labor to advantage at all seasons of the year, either in lumbering or in clearing land, seasonal distribution of farm labor has not yet become an important problem in recently settled sections.

14. A large amount of family labor is available, much of which is not used to advantage.

15. The crop area per horse is too small for the most profitable use of labor.

16. Small irregular fields and numerous stumps prevent the most efficient use of farm machinery.

17. Few farmers in this district are rapidly accumulating wealth, but, with economy and good management, there is an opportunity to make a living and a little more.

DESCRIPTION OF THE AREA.

The cut-over district in the northern part of Michigan, Wisconsin, and Minnesota extends in a broad belt from St. Marys River and Lake Huron on the east to the Red River Valley on the west. The shaded portion of the map (fig. 1) shows in a general way the boundaries of this district.

The high price of lumber in recent years has brought about the destruction of most of the pine forests in this region and has caused big inroads to be made into the forests of hardwood. Fires have also played an important part in the destruction of these northern forests. The harvesting of the crop of timber and its manufacture into lumber has made a few men very wealthy and for a long time has furnished employment to a large force of laborers at reasonably good wages.

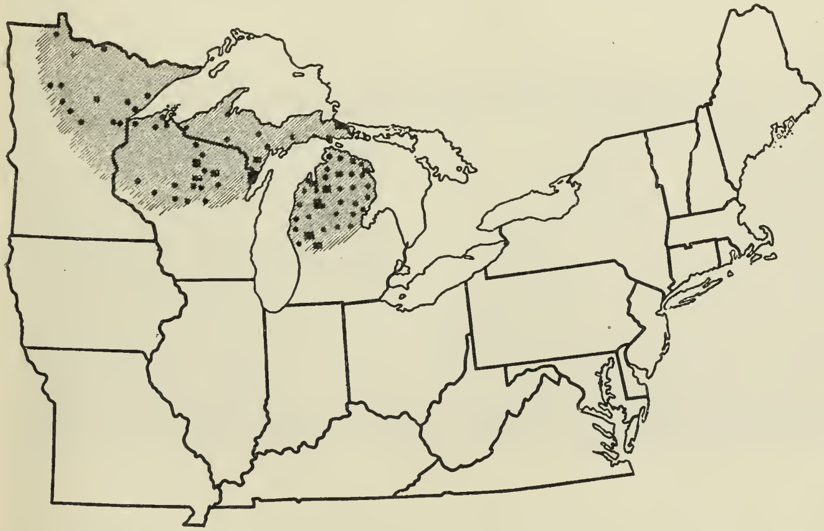

FIG. 1.—Map showing cut-over district (shaded area) and location of farms studied. Squares show areas where farm surveys were made and round dots areas where farm practice studies were conducted.

Strange as it may seem, the lumberman rated the land that produced this heavy growth of timber as having little or no agricultural value. While this may be true of some of the swamp land and sandy belt areas, it is by no means generally true of this extensive cut-over district. At present prices for farm products the very sandy lands can not be farmed successfully by the ordinary methods now in use and the swamp lands must be drained before they can add to farm profits, but a large percentage of both these soil types can and will eventually be brought under successful cultivation.

The soils of this region are largely of glacial origin, as the ice sheet at one time covered the entire district. There are large areas of swamp lands, especially in northern Minnesota and the northern peninsula of Michigan. Much of the swamp land is productive when drained and generally the cost of drainage is not excessive. As is common in most glacial districts, the soils range from light sand to very heavy clay. There is a small percentage of worthless sandy land that the prospective settler would do well to avoid, and there are larger areas of light sandy soils that can not produce large crops without fertilizers. Sandy loam and medium loam soils predominate and these when properly managed produce satisfactory yields of all crops adapted to the district. Such crops as clover, beans, peas, rye, vetch, buckwheat, corn, potatoes, root crops, and small fruits do well on the sandy loam soils. These crops also do well on the heavier soils, and in addition these richer soils produce satisfactory crops of timothy, wheat, oats, and barley.

The winters in this region are usually long and cold, with a heavy fall of snow. Ordinarily the summers are short and hot, with ample rainfall, well distributed. Late frosts in spring and early autumn frosts limit the kinds of crops that can be grown, yet early varieties of corn mature in the southern portion of this belt and make good silage over a large portion of this area in the average year.

Forest products and rich iron and copper mines have brought the railroads to almost every part of the region. These enterprises have also caused the growth in this district of many towns of considerable size and a few comparatively large cities. The railroads and Great Lakes furnish excellent shipping facilities for agricultural products and the towns and cities furnish good local markets. Wagon roads are generally poor, though there is ordinarily good material for road construction close at hand. Scattered population and lack of funds have prevented the rapid building of good wagon roads. It is also true that until recently there has been little in the way of agricultural products to be hauled over the roads, consequently there was small demand for road improvement. Considering the undeveloped condition of the country, school advantages generally are very good.

The cut-over district is exceptionally well watered. Many small streams and lakes are distributed over the region. (See fig. 2.) Nearly everywhere wells of moderate depth furnish an adequate supply of first-class water.

TYPE OF FARMING.

In most parts of the cut-over district definite types of farming have not yet become established. Over a large part of this area conditions are especially favorable for the development of dairying. The relatively large acreage and high yields of hay, together with fair yields of silage corn over much of this section indicate a promising future for the dairy type of farming. The survey records indicate that dairying and hog production, combined with a moderate acreage of one or two money crops, is proving a satisfactory type of farming on a large percentage of the farms of this region. Mixed farming rather than a highly specialized type is apparently well adapted to the majority of farms in this district.

Table 1 shows the average area, capital invested, and income[1] of 801 farms in the cut-over district. The average size of these farms is 108 acres, of which 55.2 acres, or practically one-half, are tillable and 52.8 acres are nontillable. In addition to all the unimproved land that may possibly be brought under cultivation, the term "nontillable area" as used here includes the nonproductive lands taken up by farmsteads, roads, streams, timberland, etc.

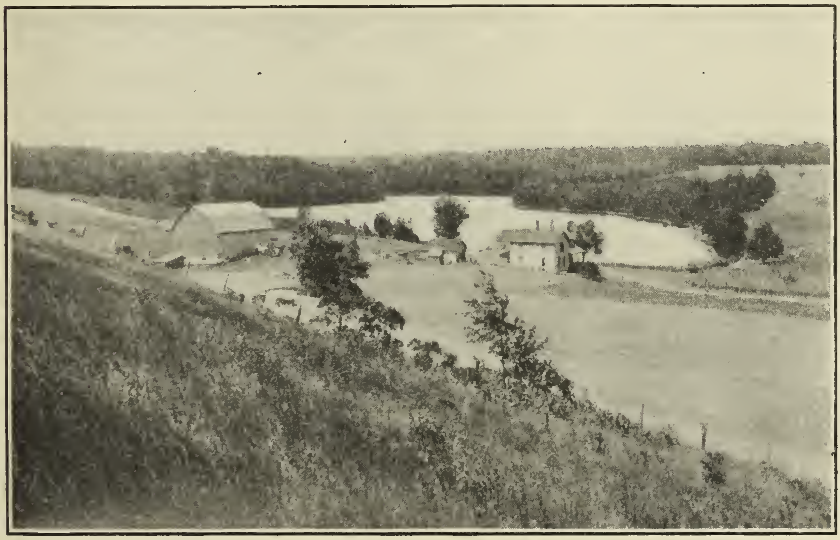

FIG. 2.—In some parts of the region lakes and streams are numerous.

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[1] The following definitions may be found helpful in studying the tables:

a. Family labor is the unpaid farm labor furnished by the family, not including the operator's labor.

b. Labor income is the amount left the farmer for his services after all expenses, except the value of his labor, have been deducted. Family labor, depreciation, and interest on total investment, are included among these expenses. In addition to labor income, the farmer has his home and what the farm furnishes directly toward the family living.

In this bulletin interest is figured at 5 per cent.

c. Farm income is total receipts minus all expenses except the value of the operator's labor and interest on total investment; or, farm income is labor income plus interest on total investment.

d. Family labor income is total income minus all expenses except the value of the operator's labor and family labor; or, family labor income is labor income plus value of family labor.

e. Family income is total income minus all expenses except the value of the operator's labor, family labor, and interest on total investment; or, family income is labor income plus value of family labor, plus interest on total investment.

TABLE 1.—*Area, capital invested, and income per farm.*

[Average of 801 farms.]

Tillable area	acres	55.2
Nontillable area	do	52.8
Size of farm	do	108
Capital invested		$6,856
Family income		$559
Family labor income		$217
Farm income		$391
Labor income		$49

The average investment per farm is $6,856, and the family income $559. Thus, if free of debt, the average family has a home, $559 for living expenses, and, in addition, what the farm furnishes toward the family living. The low labor income of $49 shows that these farms are not doing well as a business proposition, but the small investment, coupled with a fair family income, demonstrates that as a rule those not burdened with heavy debts are in comfortable circumstances. A large percentage of the settlers are foreign born. They are industrious and economical, and while their income is small, their expenses are relatively low.

CROPS.

The latitude of this section limits the number of crops that can be grown successfully as major farm enterprises. From the standpoint of acreage, hay is of greatest relative importance. This crop occupies approximately 40 per cent of the total crop area of the farms surveyed. On these farms oats is second in importance, occupying 20 per cent of the total crop area. Corn occupies but 14.6 per cent. This acreage will undoubtedly be increased as earlier varieties are developed. The State experiment stations and local substations are doing splendid work along this line. A good proportion of the present acreage of corn is grown for silage. Potatoes occupy about 9 per cent of the total crop area, which places this crop next below corn from the standpoint of acreage. There are a number of other crops grown but these are of minor importance. Table 2 shows the average acreage of the different crops on the 801 farms surveyed. Figure 3 shows the relative importance of the acreage in each of these crops.

TABLE 2.—*Percentage of crop area devoted to each crop.*

[Average of 801 farms.]

Crop.	Acres.	Per cent.	Crop.	Acres.	Per cent.
Corn	7.0	14.6	Peas	0.6	1.2
Potatoes	4.3	8.9	Beans	1.1	2.3
Wheat	1.5	3.2	Roots	.1	.2
Rye	2.1	4.4	Fruit	1.2	2.5
Oats	9.7	20.2	Truck	.2	.4
Barley	.5	1.0			
Buckwheat	.6	1.2	Total	48.1	100.0
Hay	19.2	39.9			

These results should not be taken to mean that the present acreages of crops represent an ideal cropping system for this region. While all these crops are commonly grown in this section there is probably no one farm that ever produces all of them. While hay and potatoes are two of the leading money crops, these crops are not grown extensively on every farm. Of these crops hay covers the largest acreage, but the selling of this crop is by no means a universal practice.

LIVE STOCK.

While some live stock is kept on nearly every farm, this industry has not reached its full state of development in the region as a whole. Aside from dairying, comparatively few farms are devoted exclusively to live-stock enterprises. The average of all farms surveyed shows about 14 animal units[1] per farm. Table 3 gives the average number of animal units per farm and the percentage of each class. Figure 4 shows the relative importance of each class of live stock.

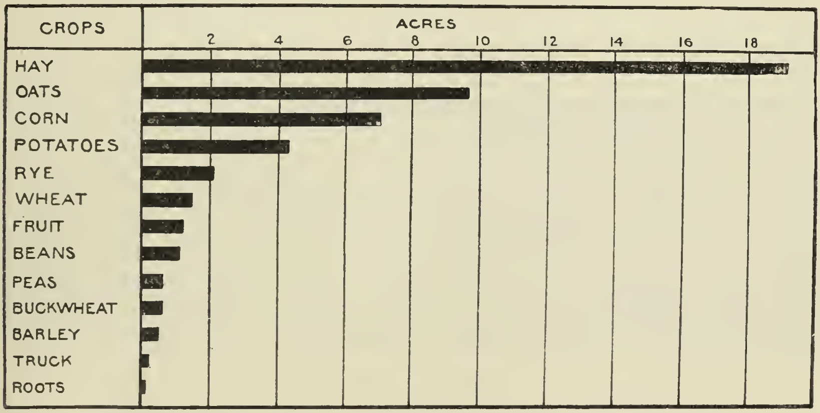

FIG. 3.—Acres of crops per farm. (Average of 801 farms in northern Michigan, Wisconsin, and Minnesota.)

TABLE 3.—*Number and percentage of animal units of each class.*

[Average of 801 farms.]

Kind of animal.	Animal units.		Kind of animal.	Animal units.	
	Number.	Per cent.		Number.	Per cent.
Dairy cows	5.8	41.1	Sheep	0.3	2.1
Young cattle	2.9	20.6	Hogs	.8	5.8
Bulls	.3	2.1	Poultry	.5	3.6
Steers	.6	4.2			
Work horses	2.7	19.1	Total	14.1	100.0
Colts	.2	1.4			

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[1] An "animal unit" is the equivalent, from the standpoint of feed required, of a full-grown cow or horse. It is customary to count as an animal unit 2 head of young cattle or colts, 5 hogs, 10 pigs, 7 sheep, 14 lambs, or 100 poultry.

As shown in Table 3, cows represent 41 per cent of the total number of animal units, and together with young stock and bulls, comprise over 63 per cent of all the live stock. This gives some idea of the extent of dairying in the district as compared with other live-stock enterprises.

The sheep business and beef-cattle industry, though relatively unimportant, are financially successful when well managed. To be highly successful these industries require considerable capital and a thorough knowledge of the business. In both types of farming labor costs are relatively low. On the farms tabulated, steers constituted 4.2 per cent of the total animal units and sheep 2.1 per cent. A study was also made of a few selected typical sheep and beef-cattle farms. These farms had the advantage of large acreage and considerable capital. The labor incomes were very good. The average farmer in this district has not sufficient capital to buy enough animals or to control enough suitable land for beef cattle or sheep farming. Unless he can furnish winter feed he is compelled, regardless of price, to buy his live stock in the spring and sell in the fall. This tends to make the business speculative for the man of moderate means. Briefly stated, the requirements for success in the production of beef and mutton on a large scale in this territory are plenty of feed and water, sufficient capital, and a knowledge of how and when to buy and sell.

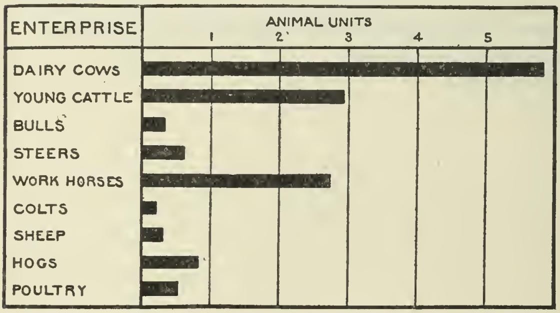

FIG. 4.—Animal units per farm. (Average of 801 farms in norhtern Michigan, Wisconsin, and Minnesota.)

Though there are not many exclusively sheep or beef-cattle farms in the district, it is not unusual to find such animals kept in small numbers at a profit. They help to utilize unimproved land. The sheep, especially, are of considerable importance in connection with the clearing of new land. (See fig. 5.) On the average farm in the cut-over district both these enterprises are at present very much limited through lack of winter feed.

The crops that can be grown successfully in this district are well adapted to the production of hogs of the bacon type. At present hogs constitute only 5.8 per cent of the animal units on each farm, but as larger acreages of corn, rye, barley, clover, alfalfa, soy beans, and Canadian field peas are grown more hogs can be produced at a profit. A good practice is to pasture hogs all summer on clover or alfalfa, then fatten them on corn, rye, or barley. The climate and the heavier soils are especially adapted to the production of barley.

Some poultry is kept on practically every farm, but there are few large poultry farms in the district. A small flock is maintained at little expense and furnishes eggs and meat for the family.

There are 2.7 work horses per farm, an average tillable area of 55.2 acres, and an average crop area of 49 acres. This is less than 21 tillable acres and about 18 crop acres per horse. The horses could cultivate more land profitably. At present, however, they are used in clearing and in breaking new land, and during the winter months they are frequently employed in the lumber woods.

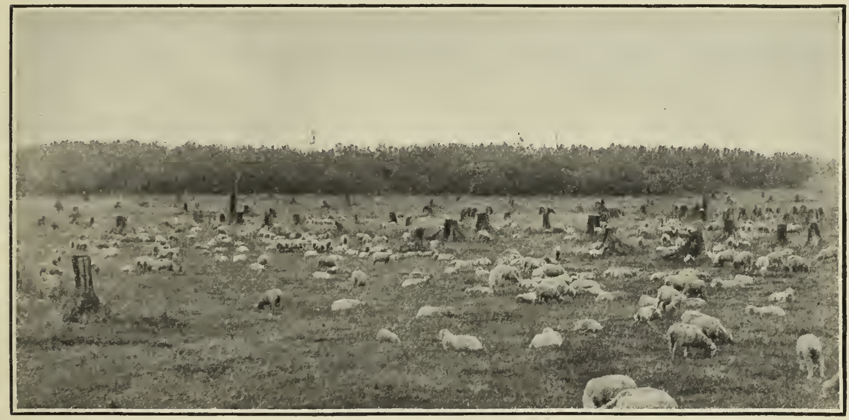

FIG. 5.—In some sections sheep are valuable in utilizing pasture and for destroying second-growth sprouts.

RELATION BETWEEN INCOME AND TILLABLE AREA.

That there is a definite relation in this district between income and acreage under cultivation is clearly shown in Table 4.

TABLE 4.—*Income as affected by tillable area.*

[Average of 801 farms.]

Tillable area per farm.	Farms in group.	Tillable area.	Size of farm.	Capital.	Family income.	Family labor income.	Farm income.	Labor income.
		Acres.	*Acres.*					
20 acres or less	50	15.5	60	$3,593	$213	$33	$62	−$118
20.1 to 40 acres	246	31.6	77	5,011	339	89	194	− 56
40.1 to 60 acres	237	50.2	107	6,620	533	203	377	47
60.1 to 80 acres	151	68.8	124	7,707	622	237	437	52
80.1 to 100 acres	54	88.9	148	9,488	939	467	667	195
100.1 to 140 acres	43	115.1	169	11,099	1,179	626	1,016	463
Over 140 acres	20	179.5	254	17,872	1,586	693	1,388	495
Total and average of all farms	801	55.2	108	6,856	559	217	391	49

In this table the farms are classified on the basis of tillable area. In a region like this, having a very large percentage of unimproved land, it is better to measure size of business in tillable area than in total area. Family income, family labor income, farm income, and labor income are also shown in the table. These incomes increase in direct ratio to the increase in tillable area. The 50 farms in the first group with an average tillable area of 15.5 acres have an average labor income of minus $118 and an average family income of $213. These incomes constantly increase with each group until in the last, with an average tillable area of 179.5 acres, the average labor income is $495 and the average family income $1,586.

The average amount of capital invested in the first group is $3,593 and in the last group $17,872. The average total investment for the 801 farms is $6,856. As compared with some areas studied in other parts of the country, the average incomes are not large, but it must be remembered that the average investment is small. These figures show what is being done with small capital and small clearings, and indicate what may be done with more capital and with larger acreage under cultivation.

SIZE OF FARM.

All these groups, except possibly the last, contain enough farms to warrant the drawing of definite conclusions as to the relation existing between income and size of business as measured by tillable area. The "little farm well tilled" may succeed, and frequently does succeed in this area, but the prospects are brighter for the larger farm if that larger farm has sufficient area under cultivation. Among the records there are those of quite a number of farms having satisfactory labor incomes on less than 40 acres of cleared land, but these farms have rich soil, exceptionally good livestock, and, as a rule, a considerable acreage of woods pasture. A family engaged in general farming may make a fair living on a farm with 40 acres under cultivation and should be able to make money with 80 to 160 acres under cultivation. The rapid enlargement of the cultivated area on each farm, when it can be done economically, is the first and most important agricultural problem in this district and the one that has the widest and most general application.

How large the farm should be in this region will depend much on the farmer's resources. The average farm in the third group with 50.2 tillable acres produces a family income of $533. If the farm is free of debt, all of this money is available for the family living, but if family labor and interest are deducted, the farmer has only $47 left to pay him for his year's work. The next group of farms, with an average of 68.8 acres under cultivation, gives results only a little better. The following group, having a tillable area between

80.1 and 100 acres, with an average of 88.9 acres, gives much better results. In this group the farmer receives $195 a year for his labor, and the farmer and his family receive $467 a year for their labor. If free of debt, they have a family income of $939 on which to live. While there are individual farms of all sizes that are financially successful, this is the first group of farms in the series that has large enough area under cultivation to produce satisfactory average incomes. The next group with greater tillable area shows larger net returns, and the last group has an average tillable area of 179.5 acres, a labor income of $495 and a family income of $1,586. These would be considered very satisfactory incomes for any agricultural section of the country. None of the farms studied in this district was too large in tillable acres. Briefly stated, the figures show that for the northern cut-over district a farm with 50 acres of rich land under cultivation usually produces a good living for a family of average size, and that 90 acres of rich land under cultivation is a fair foundation for business success.

Figure 6 shows in graphic form the data given in Table 2.

The curves show that the incomes advance about in proportion to the increase of tillable area, except that the incomes advance very slowly as the cultivated area is increased from 50 to 70 acres. The slow gain in income at that stage is doubtless due to the fact that there is a transition period between the small farm and the large farm where labor and equipment are used less efficiently than on farms that are either below or above that size.

UNIMPROVED LAND.

Some of the more important problems of the cut-over district are in connection with the utilization and development of the unimproved farm area. Table 1 shows that the average size of farm in the district is 108 acres and that approximately one-half this area is tillable and about one-half is nontillable. Table 4 shows that the group of farms having less than 40 acres tillable made minus labor incomes and only the groups having 80 acres or more of tillable land made a labor income above $100. This table further shows that in the first group the average farm area is only 60 acres, about one-half of which is tillable. The second group has an average farm area of 77 acres with less than one-half tillable. Both these groups made minus labor incomes. These figures bring out the fact that more of the unimproved farm area should be brought under cultivation. Indeed this is the most logical way of increasing the farm business since it not only increases the earning capacity of the farm but at the same time cuts down the burden of unimproved land the farm must carry.

After deducting from 5 to 10 per cent of the farm area for land taken up by woodland, building lots, roads, and streams, practically 20 per cent of the farm area in the first group of farms is unimproved. The percentage of unimproved land gradually increases throughout the different groups to practically 60 per cent in the last two groups. The chief expense of carrying this unimproved land consists of taxes and interest. In figuring profits from a business standpoint, interest on the investment in land must be considered.

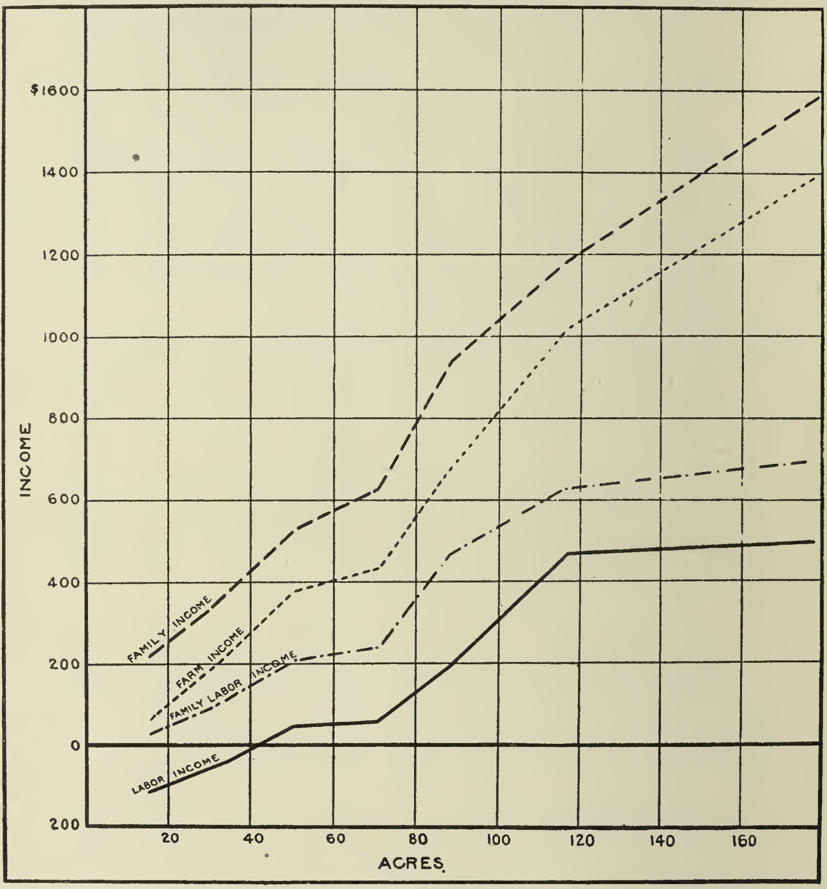

FIG. 6.—Relation of tillable area to income. (Average of 801 farms in northern Michigan, Wisconsin, and Minnesota.)

The wisdom of owning a large acreage of unimproved land depends largely on the prospect of future advance in price of land and the rapidity with which such land can be developed. Wherever possible unimproved land should be made to yield some returns. On many of these farms some income can be derived from the sale of lumber, wood, and fence posts. In this way these lands furnish profitable employment during the winter season. As fast as possible unimproved land should be put into condition to grow grass and should be used as pasture for live stock.

LAND CLEARING.[1]

A large part of the nontillable land in this district is covered with large stumps. Clearing is difficult and requires much heavy work and considerable capital. In order to develop this country rapidly, more farmers with capital are needed. To the settler with small capital the clearing of land will necessarily be slow but not impossible. Ordinarily the cost of clearing land ranges from $20 to $60 per acre, depending mainly on the kind, condition, number, and size of stumps; the acreage to be cleared; the amount of wood and brush that must be removed or burned; and the quality and condition of the soil. A part of this cost may frequently be offset through the sale of wood products. Small stumps when numerous are most economically removed by means of stump pullers, and larger ones by the use of dynamite or a combination of the two methods. Ordinarily the cost of removing stumps ranges from 20 to 75 cents per stump. Stumps of all kinds are much more easily removed if considerable time has elapsed since the timber was cut. (See fig. 7.)

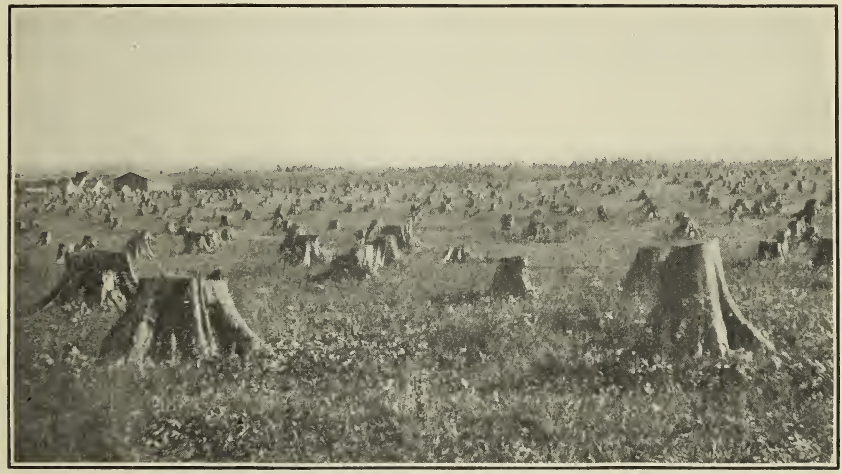

Fig. 7.—A stump-land pasture. Seeding the land to grass and pasturing for several years lessens the cost of clearing.

Most varieties of hardwood stumps decay in a short time, but white and Norway pine stumps remain comparatively sound for many years. For this reason hardwood lands, other things being equal, are more in demand. It is important in all cases to make sure that the quality of land justifies the expense of clearing.

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[1] For detailed information concerning land clearing see the following bulletins: U. S. Department of Agriculture Bulletin No. 91, entitled "Cost and Methods of Clearing Land in the Lake States;" Minnesota Experiment Station Bulletin No. 134, entitled "Land Clearing;" and Wisconsin Experiment Station Bulletin No. 216, entitled "Use of Explosives in Clearing Land."

FAMILY INCOME.

From the standpoint of economic well-being the family income is the item of greatest importance in the operation of the farms in the cut-over district. In computing labor income the value of the family labor is properly considered an expense and is charged against the farm, but labor income is merely a measure of the success of the business management of the farm, while family income is the real measure of the resources available each year to meet all obligations. If the farm is free of debt, the entire family income is available to the farmer and his family to meet the expense of living and to get ahead. In addition they have a home and what the farm furnishes toward the family living. Table 5 classifies these farms on the basis of family income.

TABLE 5.—*Farms classified on basis of family income.*

[Average of 801 farms.]

	Less than 0.	0 to $300.	$301 to $500.	$501 to $1,000.	$1,001 or more.
Family income	−$140	$162	$397	$710	$1,457
Number of farms	46	216	183	231	125
Percentage of farms	6	26	23	29	16

This table shows that only 6 per cent of the farms failed to make incomes above farm expenses. A study of the records of the farms with minus family incomes gave evidence that at least some of these families have small incomes from outside sources. Of the 801 farms, 16 per cent produced a family income above $1,000; 29 per cent, $501 to $1,000; and 23 per cent, from $301 to $500.

LABOR INCOME.

For the year 1914, 3 per cent of the farms surveyed made an average labor income of $1,450, 9 per cent $700, 11 per cent $398, and 28 per cent $134. The following table shows that 51 per cent of the 801 farms studied made plus labor incomes.

TABLE 6.—*Farms classified on basis of labor income.*

[Average of 801 farms.]

	Less than 0.	0 to $300.	$301 to $500.	$501 to $1,000.	$1,001 or more.
Labor income	−$280	$134	$398	$700	$1,450
Number of farms	395	222	88	72	24
Percentage of farms	49	28	11	9	3

These figures were secured for the crop year 1914. The year was somewhat abnormal in the small price received for potatoes, and in some of the areas studied the yield of oats was quite low because of rust. To offset this the corn and hay crops were generally good, the hay crop being exceptionally good in some parts of the district. A limited number of records taken for the years 1913 and 1915 indicate that these labor incomes are only slightly below normal.

From a strictly business point of view these farms do not appear to be successful, but they furnish a home for the family and offer an opportunity to earn a living. The owners, however, should not be satisfied with their present conditions, and indeed most of them are not.

QUALITY OF COWS AND LABOR INCOME.

The influence of quality of cows on labor income can be satisfactorily studied only on farms on which dairying is a leading enterprise. For this reason Table 7 includes only farms that have 40 per cent or more of the gross income from the sale of dairy products.

TABLE 7.—*Income on dairy farms as affected by quality of cows.*[1]

[Average of 164 farms.]

Group and tillable area.	Income per cow.	Number of farms.	Number of cows per farm.	Average tillable area.	Income per cow.	Family income.	Family labor income.	Farm income.	Labor income.
				Acres.					
Group A, less than 40 acres	Less than $50.	34	6.2	26.4	$33.7	$183.0	−$71.9	−$9.9	−$264.8
	$50 or more.	26	7.2	28.7	65.5	504.3	204.8	330.1	30.6
Group B, 40 to 80 acres	Less than $50.	34	9.7	53.5	36.5	315.7	− 34.4	81.4	− 268.7
	$50 or more.	56	9.8	57.1	72.0	771.2	346.8	546.5	122.1
Group C, 80 acres or more	Less than $50.	None.	....	....	....	....	....	....	....
	$50 or more.	14	18.4	124.8	86.1	1,487.8	668.0	1,095.8	276.0

In order to eliminate the influence of size of business, the farms are first grouped according to tillable area. Each group is then subdivided on the basis of income per cow. In each group the first subdivision includes all farms having less than $50 income per cow, and the second subdivision includes all farms on which the income per cow is $50 or more.

Group A contains farms having a cultivated area not to exceed 40 acres. In this group the farms having poor cows have practically the same number of cows and the same acreage under cultivation as the farms having the better grade of cows. This eliminates size of business as measured in number of cows and tillable area. In a similar way the influence of size of business is minimized in groups B and C.

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[1] As the term is used in this bulletin, a dairy farm is one that derives at least 40 per cent of its receipts from the sale of dairy products and not that much from any other one enterprise.

In group A the average family income on the 26 farms having the better class of cows is $504, or almost three times the average family income of the other 34 farms. Undoubtedly the farmers who kept the higher quality of cows were also better farmers than the average in other respects, yet it is fair to conclude that as dairying is a major enterprise on each of these farms the quality of the cows has much to do with producing the larger incomes.

In group B the 56 farms having the better cows have an average family income of $771, or about two and one-half times that of the 34 farms having the less productive cows. As compared with group A, a much larger percentage of the farms in this group have the better grade of cows. The ability of these farmers to eliminate the less productive cows is largely due to better financial circumstances. The larger average cultivated area as compared with group A indicates that these are generally better developed farms than those in group A. The selection of cows has, therefore, in most cases probably covered a longer period.

Group C contains no farms on which the average income per cow is less than $50. As compared with the farms having the better grade of cows in group B, the farms in group C are more than twice as large in cultivated acres, have about twice the number of cows, larger receipts per cow, almost twice the family income, and more than twice the labor income per farm. These increased incomes are therefore apparently due to a combination of three major factors: Tillable area, number of cows, and quality of cows. In groups A and B, however, all these major factors are eliminated, except quality of cows, and the larger incomes may be attributed very largely to the influence of quality alone.

The average value of cows on the 801 farms included in the survey is $57.11, and the average value of milk products per cow is $58.04. This estimate of milk products includes what the dairy furnishes the family as well as milk products sold. Such a low return yields little if any profit. With so small an area under cultivation as is found on most farms in this district, crops should be fed to better cows.

The need of more and better cows is generally recognized by farmers and business men in all parts of the district. Many of the farmers are recent settlers and not well supplied with working capital; it is therefore not an easy matter for them to pay for first-class cows. Knowing that successful agriculture is necessary to the permanent prosperity of nearly all lines of business in this district, the city business men in some sections are helping the farmers to raise money with which to purchase good dairy stock. The necessary capital is obtained from the banks, and security is guaranteed by the business men who in turn take their security on the stock purchased. Principal and a moderate rate of interest are paid monthly out of the receipts from the sale of dairy products. This plan, known from its place of origin as the "Ashland Plan," is attended with some risk to those who guarantee the loans, but in most instances it appears to have met with considerable success. When well managed, it has helped materially to improve the quality of the dairy cattle.

As the country develops, more money will become available for the improvement of dairy herds. This improvement could be greatly hastened now at moderate expense by securing better bulls. Some owners of dairy farms in this district keep first-class cows. These men are making money. On a few such farms the herd bulls are of excellent quality and breeding. For this district probably the next most important problem after increasing tillable area is the securing of more and better cows. (See fig. 8.)

FIG. 8.—Dairy herd on pasture in cut-over district.

INFLUENCE OF CROP YIELDS ON LABOR INCOME.

Table 8 shows the relation existing between crop yields and incomes. The family income is $193 higher, and the labor income $123 higher on the 355 farms that have crop yields above the average than on the other 446 farms.

TABLE 8.—*Income as affected by crop yields.*

[Average of 801 farms.]

Range of crop yields (per cent).[1]	Number of farms.	Average crop yields.	Farm area.	Crop area.	Family income.	Family labor income.	Farm income.	Labor income.
		Per cent.	*Acres.*	*Acres.*				
Above 100	355	119	107.8	49.30	$666	$292	$491	$118
100 or less	446	83	107.6	48.77	473	156	312	−5
Difference	....	36	.2	.53	193	136	179	123

[1] Average yields of all farms taken as 100 per cent.

There appears to be no relation between crop yields and crop area, as crop area is practically the same for each group. The larger yields were not due to commercial fertilizers, as practically none are used in this district.

These yields were doubtless brought about in large part through richer soil, more carefully selected seed, and better cultural methods. Whatever the cause, the fact is evident that large crop yields greatly increase the farmer's income. (See fig. 9.)

CROPPING SYSTEMS AND ROTATIONS.

In the more recently settled sections of the cut-over district the cropping systems vary greatly. On the newer farms there is often no definite crop rotation, but quite definite rotations well adapted to the district are common on the more successful of the older farms.

FIG. 9.—Good crop yields are generally maintained on well-developed live-stock farms.

The most desirable as well as the most common rotation of this district consists largely of grain, legumes, and intertilled crops. These crops are usually grown in a three or a four year rotation, as follows:

	Three-year rotation.	Four-year rotation.
First year	Grain	Grain.
Second year	Hay	Hay.
Third year	Intertilled crops	Hay or pasture.
Fourth year		Intertilled crops.

In case of an abundance of pasture on undeveloped land, the three-year rotation is in general use.

With either of these rotations as a foundation, opportunity is offered for considerable variation in the choice of crops. For example, the small-grain crop may consist of oats, wheat, rye, or barley; the hay crop usually consists of clover and timothy; and the intertilled

				1:	.47 .24 .30	.45 .47										
	1									1						
				1		.31 .15 .31				1						
	1:	-.04:	.23 .16										1			
				1			1									
													1:	.58 .27 .25		
							1:	.31 .22								
							1:	.69 .25 .28								
	1															
				1		.09 .03 .17										
										1			1:	-.03: -.07:	.17 .09	1
					-.04: -.07: -.02	.08 .06										
8				1:	.69: .54: .24	.24: .24	2			1				.69 .54 .24	.24 .24	
4 4																
				1						1						
				1						1			1			
				1					.39 .12	1						
6 5							1:	.06 .04 .24								
7 7 7	2:	.55 .24 .33		1:	-.09 -.13 -.04	.20 .61	1			1			2			2:
							1			1			1			

SEPTEM

23			24			25			26			27			
R	Price G	Price Pf	R	Price G	Price Pf	R	Price G	Price Pf	R	Price G	Price Pf	R	Price G	Price Pf	R
	$	$		$	$		$	$		$	$		$	$	
1														.23 .09	
						1	-.21 -.29 -.08	.17 .08							
												1	.12 -.11 .07	.31	1
2		.24 .05 .40	1	.48 .61 .31		5	.29 -.09 .34	.24 .11 .37	2			1			2
1															
4	1.09 .42 .46		2	.50 .21 .35	.43	8	.38 .14 .16		5	.09 -.05 .12	.15 .05 .35	7	.18 -.10 .15	.22 .04 .31	4
									1						
2	1.10 .56 .45					1	.68 .48 .28	.24 -.04	2			2	.21 -.07 .13	.20 .14	
			1	.90 .50 .43											
									1						
						1						1			
9	.74 .30 .31	.38 .16 .54	6	.73 .36 .34	.35 .18 .54	5	.40 .00 .25	.32 .17 .42	2			3	.55 .21 .26	.38 .16 .46	5
6	.05 .13 .20		4	.56 .42 .35	.49 .36 .68	2	.41 .33 .24	.46 .30 .51	3	.17 .26 .13	.13 .09	1	.77 .38	.31 .10 .47	
1			3	.27 .25	.25 .09 .46	3	.06 .02 .12	.19	2			1		.36 .23	3
1		.34 .17	1		.40 .25 .50	1		.25 .05 .38				3	.28 .15 .20	.29	
			1	-.44											

crop may include corn, potatoes, and the various root crops. Among the many other crops that are successfully grown, the following may be mentioned: Alfalfa, sweet clover, oats and peas, peas, beans, soy beans, hairy vetch, buckwheat, and millet.[1]

POTATOES.

Potatoes are a leading money crop on many farms, and practically every farm in the district produces enough for home use. They do exceptionally well when planted on a fertile loam. They do not ordinarily yield so well on compact clay or light sand, but potatoes grown on sandy soils are generally of excellent quality.

The cost of raising potatoes in this district is comparatively low, as commercial fertilizers are seldom used. Yields are greatly increased by the use of barnyard manure. The application of 10 tons of barnyard manure per acre often doubles the yield. Potato growing combines well with dairying and furnishes an excellent opportunity to turn the manure of the dairy herd into a direct profit. (See fig. 10.)

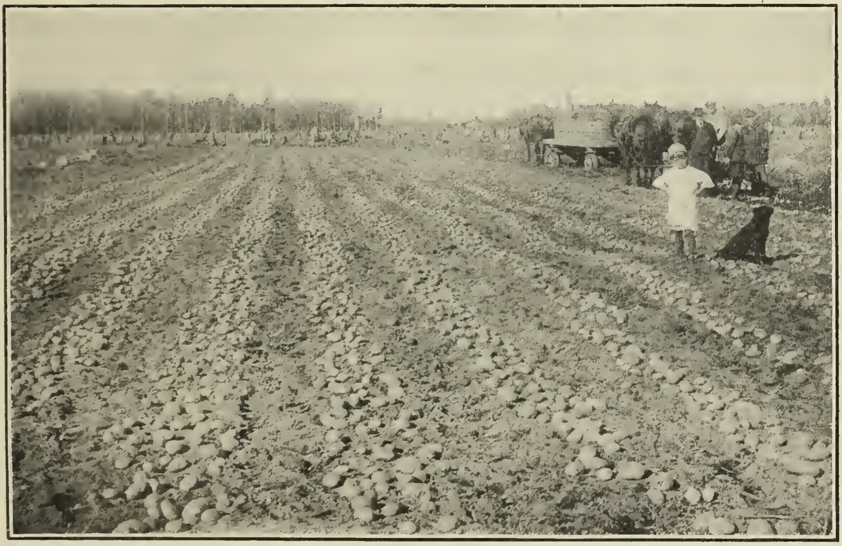

FIG. 10.—Potatoes on cut-over land. A moderate acreage of potatoes is generally a satisfactory cash crop.

CORN.

Early varieties of corn yield well in the southern part of this district and make good silage in a considerable portion of the area. Varieties especially adapted to the various parts of the district have been developed by the State experiment stations and by the local substations. In many parts of the district the value of a silo to a farm depends largely upon the number of cows kept and the success with which corn can be grown on that farm during a series of years. Root crops are used as a substitute for silage on many of the farms studied.

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[1] Wisconsin Experiment Station Bulletin No. 260, "First Aid to the Settler."

CLOVER.

Clover does exceptionally well in practically all parts of this region. Good yields are ordinarily secured without the aid of artificial inoculation or lime. Clover or clover and timothy are the most popular hay crops grown in this section. Medium red clover yields two crops in one season. The first crop is cut for hay and the second either for hay or for seed.[1] Two tons of hay from the first cutting and one from the second is a common yield, and it is not at all uncommon for clover seed to yield two bushels per acre. The clover-seed crop is somewhat uncertain, but in case it does not promise a fair yield of seed, by careful observation the farmer can usually determine this in time to cut the crop for hay.

ALFALFA.

Alfalfa can be grown successfully in nearly all parts of the region, but certain requirements are usually essential. Drainage, manure, a deep, compact, clean seed bed, lime, inoculation, and good seed insure a stand of alfalfa on the average soil of this district in any ordinary year. Alfalfa yields more hay per acre than clover, but it does not fit so well into existing rotations.

SWEET CLOVER.

Sweet clover is still in the experimental stage in this region, but is yielding satisfactory returns on a few farms. Soil preparation for sweet clover is about the same as for alfalfa. For hay and pasture it is less palatable than alfalfa. It seeds heavily, and the high price of the seed makes it a good cash crop. Sweet clover inoculates and in other ways prepares the soil for alfalfa.

HAIRY VETCH.

Hairy vetch is still in the experimental stage in this district. It is usually grown with winter rye. When sown late in the fall it sometimes winter-kills badly, but a good stand yields well and the seed usually sells at a high price. The crop is grown for seed, for hay, and for soil improvement. The common fanning mill does not separate vetch seed from rye, but there is a gravity spiral machine now on the market that makes a very complete separation.

CASH CROPS.

The following are good cash crops for this district: Potatoes for seed or market, hay, clover seed, peas, beans, hairy vetch, seed corn, rye, wheat, barley, and buckwheat. Limited amounts of small fruits and vegetables may be grown profitably where satisfactory markets are available. Of these, potatoes are most commonly grown as a cash crop. This is perhaps as it should be, because while their heavy yield uses much plant food, and they vary greatly in price, they are a comparatively certain crop and the yield in this section is generally satisfactory. In selling the seed of the legumes enumerated above, and of seed corn, soil fertility is usually sold at so high a price that the practice can safely be recommended. The selling of rye, wheat, and buckwheat on the general market is a practice, however, that should not be long continued without considering its effect on soil fertility. Hay is an important cash crop in certain sections of the region. While the practice of selling hay is undoubtedly yielding fair returns on many fertile farms in the cut-over district, here also care should be taken to see that the question of soil fertility is not being overlooked in the desire to increase present income.

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[1] U. S. Department of Agriculture Farmers' Bulletin No. 323, "Clover Farming on the Sandy Jack Pine Lands of the North."

EFFICIENCY AND DISTRIBUTION OF LABOR.

The rapid development of this northern country requires much heavy work. As farms become more improved the efficiency of field labor will increase. The labor on crops is now at a disadvantage on account of stumps and small irregular fields. In clearing land, horses and dynamite should take the place of man labor wherever practicable. One very efficient farmer, who has cleared quite a large Wisconsin farm, remarked: "In clearing land I do nothing I can make my horses do, and I make my horses do nothing that nature, if left to herself for a year or two, will do."

On a majority of the farms there is so little land under cultivation that the question of seasonable distribution of the labor among the various farm enterprises is still of minor importance. The opportunity to work in the woods for wages and to clear land on the home farm will for some time to come offer ample opportunity in the way of work for both men and horses at all periods of the year. Such work as the handling of timber and the clearing of land is very difficult and the pay comparatively small, yet when this work is done for wages it furnishes a living to the new settler until he gets enough land cleared to support his family from the income of the farm.

HOME AND FARM SUPPLIES.

A study of the farms of this district emphasizes the importance of producing home supplies. Vegetables and small fruit for home use can be, and in most cases are, produced in abundance. Close to the cities and larger villages some income may be secured from the sale of such crops, but generally it pays to produce only as much of these as can be used at home. The typical farm in this district furnishes milk, butter, eggs, meat, vegetables, and small fruit for home use and sells one or more of these products. On nearly every farm there is an abundance of firewood and plenty of good timber for fence posts. Lumber, stone, sand, and gravel needed in the construction of farm buildings can usually be secured on the farm or in the immediate vicinity. As a rule the farmers of this district are very quick to recognize the advantages to be secured by reducing the living and farm expenses to the minimum.

COMMUNITY BREEDERS' ASSOCIATIONS.

More and better live stock is needed on the farms of this district. There are already a number of wide-awake community live-stock organizations. They are accomplishing much that would be impossible to individuals working alone. Cooperative ownership of sires makes it possible to secure animals of a quality far beyond the reach of the individual farmer. More economical advertising, cooperative buying and selling, prevention and eradication of animal diseases, and the raising of standards due to education and competition, are a few of the advantages to be secured through community breeders' organizations. To improve the dairy herds of this district more cow-testing associations are greatly needed. A community desiring to take up work along any of these lines should communicate with the State agricultural colleges, with one of the substations within the district, or with the local county agricultural agent.

SELECTING A FARM.

Great care should be taken in selecting a farm in the cut-over district. The price of unimproved land, from which most of the valuable timber has been cut, usually varies from $5 to $25 per acre, depending on quality of soil, topography, and location. Improved farms, including buildings, are ordinarily held at prices ranging from $25 to $100 per acre. The range in price between the most desirable and the least desirable undeveloped agricultural land is now a matter of only a few dollars. When the region becomes thickly settled and these lands are improved, the difference in value per acre will undoubtedly be much greater than the present difference in price. During this period the better soils should also yield larger net profits per acre. The prospective purchaser of farm land will, therefore, be amply repaid for time and expense of making careful investigation of soil, topography, drainage, water supply, amount of salable timber, cost of clearing, markets, schools, and social conditions. He should reserve a part of his capital to develop the farm and to support his family until he can get a fair acreage under cultivation.

Before buying land careful examination should be made of both the soil and subsoil.[1] Soil fertility is purchased at less cost in the form of rich soil than in the form of commercial fertilizers. For most crops medium loam soils are best. Heavy soils are especially adapted to the production of hay. A clay subsoil, if not so compact as to interfere with drainage, is very desirable.

Of all the items to be considered from the business point of view, in selecting undeveloped land in this region, probably the one least likely to receive proper attention is the labor involved in clearing the land of stones and stumps. The expense of removing white pine stumps with dynamite or stump pullers should be carefully estimated for all parts of the farm before actually making the purchase. The cost of bringing pine land under successful cultivation ranges from $30 to $60 per acre, while about one-half that amount should pay for clearing hardwood land of the same quality.

GENERAL SUGGESTIONS.

1. It is possible, but not easy, to start farming here with very little capital. The total capital of the average farm studied is $6,856 and the average family income only $559. This is little enough on which to live, even when none of it has to be used to pay interest.
2. Select a farm well located with reference to markets and schools. Select a soil well adapted to the desired type of farming.
3. Buy good land. It is cheaper in the long run than poor land.
4. Do not pay too much for the farm. Remember you really get nothing for your work until interest is made on total investment.
5. Avoid the burden of too much undeveloped land, and, if possible, make every acre pay its way.
6. Enlarge the cleared area as rapidly as practicable. Be sure that the quality of land justifies the expense of clearing.
7. Use good bulls from high producing dams.
8. Plant good seed. It costs little more than poor seed and yields greater profits.
9. Grow clover, alfalfa, and other legumes. These crops furnish excellent feed and improve the soil.
10. The farm should furnish home supplies such as vegetables, small fruits, eggs, meat, and milk.
11. Keep horses busy at profitable work as many days in the year as possible.
12. Do not waste family labor on unprofitable work just because such labor is cheap.
13. Keep posted on market prices and grades. Prepare products according to these standards. Work for the advancement of the

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[1] Soil maps of many parts of the district can be obtained from the U. S. Department of Agriculture and from the State experiment stations.

community. Help improve roads, schools, and markets. This will actually pay in dollars.

14. The agricultural papers in each of these three States are giving special attention to the development of this region. Many of their articles are direct from the farm, written by practical men, and are well worth reading.

15. Get in touch with the State experiment station, local substations, and the county agricultural agents; they can help. Secure lists of the bulletins published by the State experiment station and by the United States Department of Agriculture. Ask for such bulletins as you think may assist you in your work.

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in Oregon, bulletin by Thornton T. Munger	418	1–48
See also Pine, western yellow.		

PRESERVATION REVIEW

11/04

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